Multidisciplinary Task Force Review of Selected Second and Third 2003 Calendar Quarter Occurrences and Analysis of Management Systems at Brookhaven National Laboratory

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EXECUTIVE SUMMARY

There were ten reported occurrences at Brookhaven National Laboratory (BNL) between May 30**,** 2003 and September 10, 2003, of which eight occurred in a four-week period from August 11, 2003 to September 10, 2003. Three of the ten occurrences resulted in injuries and three additional occurrences had the potential to have resulted in injury.

A Multidisciplinary Task Force was charged to examine the recent series of reported occurrences, review the facts and circumstances of these incidents, and evaluate the causes of these events. The Task Force also was charged to determine if there are common causes indicative of an underlying breakdown in BNL's management systems, and to perform any needed analysis to determine if a programmatic breakdown exists.

It became readily apparent at the very beginning of this effort that BNL does not have safety management ***information*** systems. There are several ***data*** systems available, but these are not configured to provide the ***information*** necessary to discover and evaluate trends. Much of the Task Force's effort was spent capturing data and developing it into useful information. Thus, there is a breakdown in BNL's Safety Management Systems. It also became apparent early on that the depth and breadth of the investigations varied widely, and the Occurrence Reporting and Processing System (ORPS) classifications were susceptible to some subjectivity. This factor makes it difficult to trend data because the data may not be correct or at least held to some standard of quality. This was identified during the reanalysis of the ten ORPS occurrences that triggered this investigation.

The causal analyses indicate that failure to adequately plan work and to follow established procedures contribute to a high number of ORPS and Radiological Awareness Report (RAR) incidents. The analyses further indicate that these failures stem from "cultural" factors rooted in organizational and worker attitudes of overconfidence and complacency, exacerbated by budgetary and scheduling pressures and poor organizational health resulting from weakened interim leadership.

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A. Background

There were ten reported occurrences at Brookhaven National Laboratory (BNL) between May 30**,** 2003 and September 10, 2003, of which eight occurred in a four-week period from August11, 2003 to September 10, 2003. Three of the ten occurrences resulted in injuries and three additional occurrences had the potential to have resulted in injury. A listing of those Occurrence Reporting and Processing System (ORPS) occurrences is provided in Table 1.

Table 1. ORPS Occurrences Evaluated by Task Force

2003 Date	ORPS Occurrence
May 30	Employee slips on floor and injures elbow
June 27	Employee received an electric shock to hand
August 8	Failure of machining arbor in heavy machine shop
August 12	Forklift load strikes overhead lines
August 27	Rail car movement while loading
August 29	Defective north face air purifying respirator
September 4	Lifting magnet device releases steel plate during lift
September 4	Injury to hand while operating lathe
September 9	Graduate student incurs laser injury to eyes
September 10	Elevator oil line breaks during preliminary acceptance testing

B. Charge

The increased frequency of occurrences warrants careful review to determine if there are common causes indicative of an underlying breakdown in BNL's management systems. Monitoring reported occurrences, in conjunction with other management assessment tools, can serve as an early warning system for adverse trends. The charge of the Multidisciplinary Task Force was to examine the recent series of reported occurrences, review the facts and circumstances of these incidents, evaluate the causes of these events and perform any needed analysis to determine if a programmatic breakdown exists.

C. Purpose

The purpose of the Task Force was to:

- Examine recent ORPS occurrences
- Review facts and circumstances
- Evaluate cause(s) of occurrences, and
- Conduct a site-wide investigation for potential programmatic breakdown

D. Task Team Members

The task team members included:

- Steve Kane, Physics Department (Chair)
- Mike Duffy, Battelle Corporate
- Joe Labas, Quality Programs and Services
- Terry Monahan, Safety and Health Services Division
- Marty Fallier, Plant Engineering
- Carol Creutz, Chemistry Department
- Maria Dikeakos, DOE/BAO
- Paul H. Jones, DOE/BAO

II. Analysis of Ten Most Recent Incidents

A. Analyses Conducted

A subgroup of the Task Force was assigned to reinvestigate and reanalyze each of the ten ORPS occurrences. The ***5 Whys?***-technique was employed by the subgroup because it was a familiar process, and because it was different than that used by the ORPS investigators. The ORPS investigators were asked to brief the subgroup on their investigation. In most cases, the subgroup had additional questions of the investigators, which essentially expanded the depth of the investigation and the determination of the causal factors. For a first categorization of the Causal Factors for the ORPS Occurrences, the subgroup used the Causal Factor Classifications from the Battelle Memorial Institute (Appendix B). These classifications were chosen because the ORPS codes were in a state of flux at the time the Task Force was working, so an independent set of classifications was chosen to avoid confusion. These classifications are correlated with the ORPS codes in existence at the time of the Occurrences in Appendix C. Finally, the entire Task Force participated in categorizing the ten ORPS occurrences by the "7 Deadly Sins."

B. Summary of ORPS Occurrences

1. ORPS Occurrence 1 - Employee slips on floor and injures elbow

On the evening of Friday, May 30, two custodians, of their own volition, had decided to get an early start on the previously announced job of stripping and waxing the floors scheduled for Saturday. The early start for the job had not been announced to National Synchrotron Light Source (NSLS) staff and had not been approved by the Custodial Supervisor. At ~7:30 p.m., they reported taping and posting the area of work, then began stripping the floor. Very shortly thereafter, a NSLS staff member completed his work for the day and left his office. Upon stepping into the main hallway near his office, he slipped and fell, injuring his elbow. After initial care by the custodians, the NSLS staff member drove himself to the firehouse for medical care and was transported by ambulance to a local hospital and was subsequently admitted for a fractured elbow.

2. <u>ORPS Occurrence 2 - Employee received an electric shock to hand</u>

A superconducting magnet, cryostat, helium dewar, liquid helium transfer line, and associated magnet power supplies and controls manufactured by Cryomagnetics, Inc. were purchased by the University of South Carolina (USC), ultimately for use in the Laser Electron Gamma Source (LEGS) facility at BNL. Physicists from the USC and James Madison University (JMU) share the lead role in the LEGS-Spin-Collaboration for supplying this apparatus and bringing it on line. The manufacturer's representative and two physicists, one from JMU and the other from USC, assembled the magnet and performed the acceptance tests in December 2002. During the course of these tests, the manufacturer's representative installed an electrical heating tape on the magnet cryostat recovery port to prevent seals from freezing. This was the procedure that had been adopted at the factory.

In March 2003, the same USC and JMU physicists returned with two JMU students to operate the magnet and measure liquid helium consumption rates. While the device met its primary technical specifications, it consumed far more liquid helium than originally anticipated, with the result that its operation is more labor intensive. The USC and JMU physicists requested to come again in June and July with three students, two of these students having participated in the March measurements, to further define the helium consumption and to make measurements of the magnetic field. Their intention was to overlap with the students about 40% of the time. They were told that the BNL/LEGS staff were already oversubscribed to other activities and could provide only minimal help and supervision of the students.

The incident occurred during the third period of operation when the USC and JMU physicists were not present. On June 27, liquid helium was being transferred from a commercial 250-liter dewar, through a vacuum insulated metal transfer line into a cryostat containing the superconducting magnet mounted in the large steel yoke. This operation was similar to other helium transfers, which were performed about twice per day and required two people, except that this time it was believed that the helium line inside the magnet cryostat was plugged with frozen air. For this reason, LEGS group members with the most cryogenic experience were present to advise in the operation. Two undergraduate students from JMU were performing the actual transfer. One was standing on a portable stair, inserting the helium transfer tube into the 250-liter dewar to extract warm boil-off helium. At the same time, the other student was inserting the other end of the transfer line into the superconducting magnet cryostat to blow the warm helium onto the air plug. Both students were wearing gloves intended for protection against cryogenic burns. The students were wearing safety glasses but not face shields. The group technician had entered the area to watch the operation. As he watched, he observed the transfer tube unexpectedly slide deeper into the 250-liter dewar, which could defeat the purpose of the operation by transferring cold helium. To prevent this he reached up to tighten the seal on the transfer tube at the top of the dewar. He immediately received a shock, which he described as passing from the tip of his right finger, touching the nut on the seal, to just below the knuckle on that finger, which was presumably touching the body of the dewar. After the incident, the technician said he felt ill, and was taken to the clinic by a member of the group. At the time of the transfer, the heater on the 250-liter dewar was connected, although in the off position, and an electrical heating tape on the magnet cryostat recovery port was energized through a Variac to 90 volts. The superconducting magnet was not energized.

After the incident, the resistance between the magnet yoke (5.5 tons of steel resting on a stone floor) and building ground (an electrical conduit) was measured to be greater than 20 mega ohms. After the accident, one of the students did mention that he had received a shock on an earlier occasion. A senior person was not present at that time and, unfortunately, the student did not communicate this fact to the LEGS staff.

3. ORPS Occurrence 3 - Failure of machining arbor in heavy machine shop

On Friday, August 8, 2003, around 2230 hrs, a Tool & Instrument Maker (machinist) started to run a new batch of parts on the Haas Machining Center in the Heavy Machine Shop. A programming error, unknown to him, set the arbor spindle speed at 7500 rotations per minute (rpm), rather than the intended “design” speed of 750 rpm. The machinist recognized immediately, from the sound of the spindle rotating at high speed, that there was a problem with the operation and hit the “emergency stop” button. The spindle began a brake-enhanced deceleration. Before it could stop completely, the arbor started to bend, then broke at the point where it was clamped in the tool holder. The broken section of arbor was projected upward, above the protective “chip door” and the operator’s head, striking a structural vertical I-beam approximately 11 feet away and 14 feet above the floor. The piece bounced off the I-beam, striking a second horizontal structural member 2 feet away and then continued back parallel to the first path of travel, striking the electrical panel of the machining center and falling to the floor. There was no personnel injury and only minimal damage to property (e.g., broken arbor).

The cutting tool was a Central Shops fabricated/assembled arbor having a 1-inch diameter shaft that was approximately 18 inches long. At one end of the arbor was a set of eight (8) carbide saws, (0.030-inch x 3-inch O.D and 1-inch I.D.) separated by spacers which were set up to cut a series of parallel slots 0.030 inch wide by 0.060 inch deep in the G-10 material.

The decision was made to perform the job on the night shift since the Night Shift Supervisor is the only one with formal training knowledgeable about programming the Haas Machining Center. It was determined that the arbor needed to be at least 18 inches long to make the slots on the largest parts. In discussing the configuration of the tool, the Night Shift Supervisor suggested to the Day Shift Supervisor that the arbor be a 2-inch diameter cold rolled steel rod with the end tapered to 1 inch to receive the eight circular carbide cutters. The Day Shift Supervisor designed the arbor using 1-inch diameter cold rolled steel with a 2-inch long by 2-inch diameter stop collar (2-inch O.D. x 1-inch I.D.) attached to the arbor with set screws because the material was readily available. The arbor was tested in the machine at 1000 rpm to check for vibration. It was decided to run the job at 750 rpm to assure stability of the arbor.

The job was started on Monday, August 4, 2003. The Night shift Supervisor wrote the program to machine the first batch using 750 rpm as the spindle speed. The machinist “proved out” the program prior to actual operation by running the machine through the entire program without actually cutting any material. By Friday, August 8, 2003, subsequent programs had been run successfully by the assigned machinist (using the arbor) for seven batches.

On August 8, 2003 around 2230 hours, the Night Shift Supervisor gave a new program to the machinist, who set up the machine to run the eighth batch. As was the normal process, the spindle began its rotation in the “home” position, (at a height of 9 feet and 1 foot above the chip guard door), but had not begun its downward descent to the working surface (approximately 44 inches off the ground). The operator immediately heard the unusual sound (resulting from the high speed) coming from the spindle. Recognizing that there was a problem with the operation, the operator hit the machine “emergency stop” button, initiating a brake-enhanced deceleration of the spindle.

It was during the deceleration process, when it was noticed that the arbor had begun to bend, and subsequently broke at the connection point where the arbor entered the tool holder. The broken section of the arbor was projected upward and away from the protective “chip door” and the operator’s head, striking a structural, vertical I-beam approximately 11 feet away and 14 feet above the floor. The piece bounced off the I-beam, striking a second horizontal structural member 2 feet away and then continued back parallel to the first path of travel, striking the electrical panel of the machining center and falling to the floor.

4. ORPS Occurrence 4 - Forklift load strikes overhead lines

On August 12, 2003 at 1050 hours within the fenced yard at the former Hazardous Waste Management Facility (HWMF), a forklift was being used to transport a trailer- mounted generator along the road passing below power and communication lines. The forklift mast contacted the lower-most cable, a telephone cable supported by a copper weld messenger cable. A spotter assigned to watch the overhead cable was dispatched to open an overhead door, and the forklift began moving the load. Tension from this contact introduced stress on the backstay cable at the pole. The backstay cable parted under the stress, resulting in the pole leaning over at about a 15-degree angle, causing the cables to sag to within about four feet of the road surface. There was no direct contact with or damage to electrical power cables (208 VAC). There were no injuries.

5. ORPS Occurrence 5 - Rail car movement while loading

On August 27, 2003 at approximately 10:30 a.m., while performing rail car loading operations at the Chemical Holes loading area, it was noticed that the car being loaded with low-level radioactive waste (soil and building debris) started to slowly roll. This car was attached to another rail car that had just been loaded. The two rail cars slowly rolled and connected with two other rail cars that had been filled the day before. The four rail cars continued rolling ~50 feet until they connected with a rail car being worked on at the loading ramp. At this point all cars stopped. After inspection of the cars that rolled, it was confirmed that the car brakes had been applied prior to commencing loading operations. A wheel chock was not installed on any of the four cars that rolled. The car at the loading ramp was chocked, which in turn stopped the slowly rolling cars from moving any further. Because the car brake had been set to some degree, the rail car movement was extremely slow, allowing all personnel to move clear of the area before the first set of railcars connected to the second set. There was no spread of contamination, no personnel injuries, the rail cars did not de-rail from the track, and there was no damage to the rail cars.

6. ORPS Occurrence 6 - Defective north face air purifying respirator

On August 29, 2003, a Radiological Control Technician (RCT) was removing his North Full Face Air Purifying Respirator (APR) as he exited a contamination area at the BNL Brookhaven

Graphite Research Reactor (BGRR), when suddenly the lens separated from the upper and lower lens clamp and face piece. There was no personnel contamination, radiation exposure or spread of contamination. The BGRR radiological personnel and respirator issuer then inspected their inventory of "ready-for-use" respirators and found that three out of one hundred and thirty respirators were found to have missing face shield retaining nuts and bolts.

Late July, early August 2003, the Waste Management Facility (WMF) modification to add a washer for decontamination of contaminated respirators was completed. During the week of August 4, 2003, Waste Management (WM) received a request to clean and sanitize approximately two hundred respirators in a period of two weeks. WM Technicians picked up one hundred and thirty respirators from across the BNL site. On August 8, 2003 WM began the process of cleaning and sanitizing respirators in accordance with WM-SOP-529, *Respirator Cleaning, Sanitation, and Inspection in Building 865, Standard Operating Procedure* (SOP) and the disassembly operator aid. On August 11th, 2003, it was observed that the newly installed decontamination washer was leaving a film (i.e., slime-like appearance) on the lens of the respirators. This concern was communicated at the plan-of-the-day meetings and discussed with management. After further investigation, it was determined that the washer should be cleaned and run through a few cycles without the use of the defoaming agent recommended by the manufacturer, and that the respirators would have to be completely disassembled and cleaned and sanitized to remove the film from the respirator lenses.

During the week of August 11, 2003, approximately sixty respirators had to have the lens separated from the face piece in order to adequately remove the film from the respirator lenses. Four different technicians, rotating assignments and duties over the course of the week, performed this activity. During the week of August 18, 2003, after successfully cleaning and sanitizing the respirators that had film on the lenses, the WM Technician(s) re-assembled the respirators in accordance with WM-SOP-529, *Respirator Cleaning, Sanitation, and Inspection in Building 865, Standard Operating Procedure*. On August 22, 2003, approximately seventy "ready-for-use" respirators cleaned and sanitized at the WMF) were returned to the BGRR.

On August 29, 2003, at approximately 10:00 a.m., a pre-job briefing was conducted and respirators were issued by the BGRR respirator issuer for use in the BGRR canal area. The technician visually inspected the respirator for deficiencies and performed a positive and negative pressure check to ensure that there was a tight fit, and that the respirator operated properly. At approximately 12:00 p.m., the technician exited the area and began removing his Personal Protective Equipment (PPE). Upon removing the APR, the lens separated from the face piece. The technician was then checked for contamination and a bioassay was taken to check for radiation exposure. There was no personnel contamination, radiation exposure or spread of contamination.

On August 29, 2003, at approximately 1:30 p.m., the WM Program Manager notified Environmental Safety and Health Coordinators, and Facility Support Representatives of the deficiencies noted, and requested that all respirators be inspected, and deficient respirators be returned to WM. Three out of the one hundred thirty respirators inspected across the BNL complex were found to be deficient.

7. ORPS Occurrence 7 - Lifting magnet device releases steel plate during lift

At approximately 1605 hours on September 4, 2003, a Tool & Instrument Maker was repositioning a heavy steel plate on a Nomura horizontal milling machine using a crane with a magnetic lifting device. He had lifted the steel plate approximately 7 inches from the table on the machine when the magnet released the steel plate, causing it to slide to the floor. The steel plate came to rest on the floor, propped at an angle against the table. No injuries occurred and no damage other than a divot in the concrete floor was observed.

On September 3, 2003, a Tool & Instrument Maker on the night shift was assigned the job to machine the Spallation Neutron Source (SNS) High Energy Beam Transfer (HEBT) Collimator Shielding Plates. The Night Shift Supervisor did not have him continue the job the day shift Tool & Instrument Maker was working on using the Nomura Horizontal Milling Machine.

Two steel plates had been ordered from stock. They were about 81” x 17 ¼” x 4”. The night shift Tool & Instrument Maker looked at the engineering drawing and noted that the finished part would be similar in weight to the stock because he would only need to take off a few inches of stock material and make a few holes to make the collimator shielding plates. The dimensions on the finished plates would be 80.5” x 16.8”x 4”. The engineering drawing stated that the weight of the finished part was 1,151 lbs. The actual calculated weight of the finished part is 1,485 lbs. The actual calculated weight of the stock material was about 1,600 lbs.

The night shift Tool & Instrument Maker stated that he did not calculate the weight of the part. He decided to use the lifting magnet that he knew had a capacity of 1,210 lbs. if lifting steel with rust/scale. He stated that he assumed it was OK to use the magnet to lift about 1,300 lbs, because he knew all lifting devices had built-in safety factors so he was still in the “safe zone” if his estimate was not correct. He assumed he was half way between the maximum capacity of 1,710 lbs. (clean surface) and the 1,210 lbs (with rust/scale). He stated that he knew of another older magnet that had a capacity of 2,000 lbs. but felt he did not need that so he did not go to the other side of the shop to get it.

The night shift Tool & Instrument Maker measured the length and width of first steel plate to find the center of the plate. He then placed the magnet in the center of the plate and lifted it with the overhead crane about 2 inches off ground. He tested that it was secure by standing on the plate while holding on to the crane. He weighs about 130 lbs. He explained that this was the technique one of the machinists taught him over 20 years ago and it has not failed him yet.

He raised the steel plate about 4 inches off the floor, moved it from the garage door where it had been dropped off earlier, a distance of about 28 feet, to the machine. He machined along the length of the steel plate, then turned the plate around and machined the opposite side. He then moved it to a staging area about 16 feet from the machine. He repeated the steps for the second steel plate, but was only able to finish machining one of the long sides of the plate by the end of the shift. He left the lifting magnet on the part in the “on” position so the part could then be lifted and rotated to machine the other long side of the plate.

He stated that he normally leaves a note on his job for the person on the day shift for continuity. This time he did not leave a note. The night shift Tool & Instrument Maker assumed that the day shift Tool & Instrument Maker would not continue this job but revert to the job he was working on previously since the night shift Tool & Instrument Maker had interrupted the job he was working on the day before.

On September 4, 2003, the day shift Tool & Instrument Maker continued working on that steel plate. He rotated the steel plate and machined the other long side as well as the two short sides. This involved lifting and rotating the steel plate several times. He moved that steel plate to the staging area and picked up and moved the other steel plate onto the machine. He completed machining one of the short sides around 1600 hours.

Around 1605 hours, the day shift Tool & Instrument Maker started to reposition the steel plate to set it up for the night shift Tool & Instrument Maker to complete machining the last side. The day shift Tool & Instrument Maker stated that he raised the steel plate about 7 inches above the machine table when the magnet released the piece, allowing it to slide off the table onto the floor. The piece of steel came to rest on the floor at an angle against the table and floor. The day shift supervisor stated that he heard the sound of the steel plate as it hit the machine/floor and went over to see what was going on.

8. <u>ORPS Occurrence 8 - Injury to hand while operating lathe</u>

On September 4, 2003, at ~14:10 p.m., an National Synchrotron Light Source (NSLS) user (herein called the “operator”) set up a piece of 3/8" brass tubing on a tool room lathe in a machine shop at the NSLS, such that the end of the tubing extended ~13" beyond the collet drawer bar take-up wheel of the head stock. He initially successfully worked the tubing at low speed. Following an adjustment, he inadvertently and momentarily activated the lathe at high speed, causing the brass tubing extension to bend by ~90˚. Upon realizing he was in high speed instead of low speed, the operator immediately switched the lathe into low speed and then to the “off” position to shut down the lathe. While switching over to low speed, his hand accidentally encountered the whirling extended tubing, thus causing the injury. The operator reported the accident and injury to the shop supervisor, and the shop supervisor informed NSLS safety and management personnel. The operator went to the BNL Clinic where personnel administered first aid for lacerations and recommended that he obtain further medical evaluation from a private physician. He was driven to a local hospital where he received additional treatment in the emergency room. He was released by the Emergency Room physician, with a recommendation to remain at home on Friday, September 5, 2003, in order to keep the hand elevated to reduce swelling.

The tubing extended ~13” beyond the collet drawer bar take-up wheel. The operator tamped paper (rag-on-a-roll) around the tubing inside the take-up wheel so the tubing would not “chatter” during rotation. The tubing extension was not supported. The operator observed the lathe rpm setting to be at ~900 if operated at low range and did not change that setting. The operator then prepared the lathe to bore out the ID of the tubing at ~900 rpm (opened ID to 0.25”), and proceeded to do so by moving the speed lever to the left (low range) and operating at ~900 rpm. This part of the job ran successfully, without incident. The operator then prepared the lathe to remove 0.066” off the OD of the tubing. Once ready, he inadvertently moved the speed lever to the right (high range) with his left hand, thus engaging the lathe at ~2700 rpm. Due to the sound of the lathe, he immediately realized that the speed range was incorrect and pushed the speed lever to the left to get the lathe into low range. He pushed so hard that his left hand slipped off the lever and continued moving to the left. As a result of the high rpms, the brass tubing was bent at a right angle and was rotating in a propeller-like fashion; the operator's left hand was hit by the whirling tubing. The operator then moved the speed control lever into the central (neutral) position thereby stopping the lathe spindle from turning and he turned off the power to the lathe using the disconnect switch mounted on the wall to the right of the lathe. It was at this time that the operator noted he had injured his hand. He wrapped his hand with "rag-on-a-roll" paper and informed the shop supervisor of the accident and injury. The operator went to the BNL Occupational Medicine Clinic (OMC) and was administered first aid by the OMC staff. The operator's wife took him to Mather Hospital, where he received further medical care.

During the preparation of the lathe, the operator interacted with the shop supervisor. The supervisor had noted the lathe set-up and the tubing extension, saw that the lathe had operated without incident during the first ID machining phase, knew that the operator was trained to Level 3 status for the lathe, and did not comment further.

9. <u>ORPS Occurrence 9 - Graduate student incurs laser injury to eyes</u>

On Tuesday, September 9, 2003 at approximately 2:00 p.m., a graduate student suffered an exposure of his eyes to laser light from a class 4 Alexandrite laser (wave length 750 nm). The student was positioned adjacent to an ultra high vacuum surface apparatus. The surface apparatus has a port where an aligned beam of laser light enters the vacuum chamber. The light impinges on a crystal mounted at a 45-degree angle to the beam. If the crystal is centered, the beam strikes the crystal and, via a mirror, is reflected to a beam dump inside of the vacuum chamber. If the crystal is removed from the path of the beam, the beam continues straight and exits the chamber into a beam dump positioned X cm from the exit port.

The student held a commercial (not scientific grade) hand mirror in the path of the beam. As the student looked at the mirror, a postdoctoral research associate (RA) was adjusting the position of the crystal. Laser light reflected from the mirror into his eyes. The student realized he had exposed his eyes and asked the postdoctoral RA to take him to the OMC. The Principal Investigator (PI) was contacted. The OMC physician realized the magnitude of the exposure and immediately had him taken to the ophthalmologist's office where he had been administered his pre-work eye exam. The PI took the student to this office by 2:30 p.m.

It was determined that the experiment takes two persons to carry out. The mechanical process of positioning of the crystal is done from a position where it is impossible to see the exit port. Monday, September 8, 2003, the PI had positioned the crystal with the help of the student. The crystal is positioned initially with the laser beam turned off. The beam is then turned on. The PI then placed a white paper in the path of the exit port. He looks at the paper to see when there is the first edge of diffuse light as the crystal is moves slightly in one direction and then looks to see the first bit of diffuse light on the other edge. In this case, one person is moving the crystal while one is looking at the light. It was regarded as not being possible to move the crystal large distances inadvertently because of the mechanism.

The student had assembled the laser and was being trained to become the laser operator in this experiment. The postdoctoral RA was the surface scientist of the experiment.

On Tuesday, the student had gone to look for the PI in order to start running the experiment. Upon learning that the PI was in a meeting with the Department Chairman, he returned to the lab and decided to start on his own.

Authorization and review documentation was viewed. It was determined that: the student had gone through the BNL and Chemistry Department check-in procedure. Both BNL and Chemistry Department check in procedures referenced the appropriate ESR number and training. The student had taken laser training and had his eye exam well before any work commenced. The box on the facility specific check-in form, indicating meeting with the Chemistry Department laser coordinator, had not been checked although all of the paperwork had been signed. A laser SOP existed for laboratory 127 but the student had not signed the SOP and this laser (received and set up by June 2003) had not been entered on the SOP. An ESR existed for the experiment. The ESR had been reviewed and updated in August and entered on the web as the current version in late August. The paper version had not been signed. This laser had not been entered on the ESR. The Chemistry Department laser policy was updated on April 28, 2003 and is linked with the BNL subject area with the proper implementation procedure. Tier I findings for the previous year were minor and not related to the operation of the laser.

It must be emphasized that the PI was in the process of personally training the student and that the judgment of ability was not delegated to anyone else in the group. Training on lasers is not delegated to any other personnel in this group and is carried out by the PI.

10. <u>ORPS Occurrence 10 - Elevator oil line breaks during preliminary acceptance testing</u>

On September 10, 2003 at 1:30 p.m., the 2-inch piping hydraulic feed line to the Building 463 south elevator failed. It released approximately 80 gallons of hydraulic fluid beneath the floor slab, which seeped back into the basement of the south stairwell through the seam between the foundation wall and floor slab.

Building 463 has two elevators; a 4,000-lb. capacity passenger elevator and a 9,000-lb. capacity freight elevator. As part of the Ground and Surface Water Protection Project, Plant Engineering Casing Replacement project (job # 9089E), Plant Engineering was removing and replacing the single wall jack/cylinder assembly of each elevator with a double-lined safety bulkhead jack/cylinder assembly in order to prevent any possible leakage of hydraulic oil into the soil surrounding the casing. The Building 463 passenger elevator had to be tested prior to acceptance of the refurbished elevator.

The offsite contractor that had performed the replacement of the elevator shaft and casing was testing the elevator operation in preparation for the formal inspection and acceptance test by a third party Qualified Elevator Inspector. Preliminary tests were being performed on the 4,000-pound capacity passenger elevator without measured load conditions in the elevator car. The first test was a pressure test under normal working pressure (240 psi) and normal operation. The second test was the stop ring test, which requires the disabling of the electrical safety limits in order to force the stop ring to be fully seated. This causes a mechanical stop of the elevator jack.

Once the mechanical stop of the jack occurs, it initiates the bypass pressure relief test to check/ensure that the bypass pressure valve is operational. The bypass pressure valve actuates at 375 psi to transfer the hydraulic fluid from the elevator jack back to the oil tank reservoir thus avoiding putting too much pressure onto the elevator piston assembly.

The contractor employees noticed that the bypass relief valve actuated but the elevator started to slowly descend slightly past the floor level. The contractor went to investigate the elevator electrical controls and the valve body, thinking these could be the cause of the descending car, and found the oil seeping out of the seam between the foundation wall and floor slab in the stairwell. The bottom of the stairway in the basement of Building 463 is approximately 15-25 feet away from the elevator pit. Oil was contained to prevent it from entering the pit. The workers closed the ballcock valve on the oil reservoir tank to prevent further oil leakage from the system.

The one-hundred-gallon reservoir tank was filled. The jack casing holds another 45 gallons of oil. Based upon inspection, about 20 gallons of hydraulic fluid remains in the tank after the spill and the 45 gallons are still inside the jack casing. Therefore, it is estimated that approximately 80 gallons of oil were lost from the system.

Original design of the 1964 elevator did not allow for visual inspection of the pipe to determine piping integrity or condition. Since the feed pipe is located under the concrete slab floor in the stairwell and basement the feed pipe will be relocated to where it will be exposed and accessible for inspection.

C. Causal Analysis

Using the ***5 Whys?***-Technique, a subgroup of the Task Force re-investigated the ten ORPS Occurrences and determined the causal factors. Event and Causal Factors diagrams were prepared for each Occurrence, and are included at Appendix A. For a first categorization of the Causal Factors for the ORPS Occurrences, the subgroup used the Causal Factors from the Battelle Memorial Institute. A summary of the analysis and the Causal Factors for each of the ten ORPS Occurrences is provided in Table 2 through Table 11. The Battelle Memorial Institute Causal Factors are included in Appendix B. Appendix C is a comparison between the ORPS Codes and the Battelle Causal Factors.

D. The "7 Deadly Sins"

The Task Force needed to determine whether there was an underlying, cultural issue responsible for the ten ORPS Occurrences. One of the members provided an article by Dr. John Dew, a noted quality expert who has consulted for BNL in the past. The article is provided in Appendix D. While Dew's article addressed cultural issues that impact quality, the Task Force felt there was a strong correlation to safety. The "7 Deadly Sins" of Dew's article were adapted to analyze the ten ORPS Occurrences, and then used to categorize the causes. The "7 Deadly Sins" are:

1. Placing budgetary considerations ahead of safety:
Organizations emphasize the short-term cost savings of ignoring safety ("safety costs money") without considering the long-term costs of failure to work safely. Failure to invest in training, personal protective gear, and the systems needed to

work safely result in injury, lawsuits, work stoppages, higher insurance premiums, fines and low morale/productivity among the most valuable resource of any organization, its people.

2. Placing scheduling considerations ahead of safety.
Organizations emphasize working fast versus working fast safely ("I don't have time for safety"). Failure to plan work and incorporate the steps needed to assure safety in the planning process is not only unsafe but often leads to additional delay. Planning is an integral part of completing work on schedule and planning for safety is an integral part of any plan. When scheduling or budget is the driver for work planning and execution of work results in mistakes that could have been anticipated and prevented, the subsequent loss of time that results can be greater than the time that would have been invested in doing things the right way in the first place.

3. Placing political considerations ahead of safety.
The organizational culture is such that it is not possible to bring problems to light because powerful persons will be offended or because of concern that the problem will reflect negatively on the reputation of the organization.

4. Overconfidence/Hubris.
The organization tolerates or fosters a culture with attitudes such as "Our scientists are the best minds in their fields." "We have a strong record of achievement over fifty years." "I've been doing it this way for years." These attitudes can lead to overconfidence that keeps us from asking questions, seeking out advice to prevent accidents, and leads to behavior that circumvents safety processes.

5. Ignorance, lack of fundamental knowledge/tunnel vision/thinking inside the box.
Organizations fail to adequately anticipate problems due to lack of awareness, education, or training whereby important aspects of the work are not understood or potential impacts are not considered. This manifests itself in activities that are undertaken where the participants are not qualified or the risks are not fully understood and accounted for. It can be countered by expert review, training, testing, audit, etc.

6. Sense of entitlement.
I'm entitled — to my job and to my benefits because of my years of service. A sense of entitlement can produce enormous inertia to change and improvement. In particular, a sense of entitlement leads to animosity toward improving processes for safe work. It is related to both factors 4 and 5.

7. Apathy resulting from lack of empowerment.
When management fails to inform and include employees about organizational performance, problems, and concerns, workers lose any sense of empowerment and lapse into apathy that prevents them taking a proactive role in executing their work prudently and safely.

The “7 Deadly Sins” analysis for each of the ten ORPS Occurrences is included in Table 2 through Table 11.

Table 2. Employee Slips on Floor

ORPS Occurrence	Employee slips on floor	
Date	May 30, 2003	
Consequence	Employee breaks elbow	
Direct Cause	Employee slips on main hallway	
	Issue A	**Issue B**
Contributing Cause(s)	1) Employee taking quickest way out of building 2) Employee pre-occupied and distracted	Hallway is wet with wax stripper; Stripper extremely slippery when combined with wax
Why?	1) Employee may have ignored caution signs 2) Job/schedule pressure	1) Custodians stripping hallway earlier than planned 2) Some, but not all, building occupants notified 3) Supervisors not notified of early start
Why?	1) Yellow wet floor sign ineffective; often ignored because these signs are often left out after the hazard has abated	1) Custodians did not follow plan 2) Custodians did not go down back corridor 3) Common practice to get a head start
Causal Code(s)	3. Work Process controls c. Hazards not (adequately) identified ▪ controls no longer effective 5. Human factors/competency f. Poor judgment i. Inattention to detail k. Unfamiliar application	3. Work process controls d. Work performance not within controls ▪ Original work plan not followed ▪ Work activities not properly authorized 5. Human Factors/competency h. Verbal Communication problem 2. Directing, Leading and Decision-making a. Inadequate Management Processes ▪ Policy not adequately defined, disseminated, or enforced
7 Deadly Sins	2. Placing scheduling considerations ahead of safety 4. Overconfidence/Hubris	2. Placing scheduling considerations ahead of safety 6. Sense of entitlement
Root Cause	The employee slipped and broke his elbow because: 1. The wet floor signs and barriers have become ineffective because of misuse; 2. Being pre-occupied, he did not pay attention and used poor judgment to enter a wet hallway that was being stripped and was more slippery than just being wet mopped; and 3. The hallway stripping was performed a day earlier than originally planned. This was not communicated to all staff. Although not authorized, it was common practice to get a head start on this type of work	

Table 3. Employee Received an Electric Shock to Hand

ORPS Occurrence	Employee received an electric shock to hand	
Date	June 27, 2003	
Consequence	Electric shock to hand	
Direct Cause	Technician received a shock while tightening a seal on transfer tube on top of dewar which was electrically connected to the wet heating tape on the ungrounded magnet helium recovery port.	
Contributing Cause(s)	Electrical charge was permitted to accumulate because the magnet was not grounded	
	Issue A	**Issue B**
Why?	Defective cryogenic design permitted icing of recovery port	Magnet was not grounded
Why?	Inadequate design review (no BNL Cryogenic Safety Review)	Lack of ground continuity check
Why?	Group leader and PI failed to follow BNL Procedures	1) Inadequate resources to oversee (supervise) 2) Inadequate safety review 3) Inadequate feedback (precursor event)
Causal Code(s)	3. Work Process controls b. Design implementation process inadequate ▪ design review not adequate g. procedures not used or followed correctly ▪ unexpected results	2. Directing, Leading and decision making b. Inadequate supervision ▪ Poor direction of workers c. inadequate management oversight ▪ no evidence of management review of work 4. Feedback and improvement a. Self Assessment not adequate ▪ precursor event not reported
7 Deadly Sins	4. Overconfidence/Hubris	5. Ignorance, lack of fundamental knowledge/ tunnel vision/thinking inside the box 2. Placing scheduling considerations ahead of safety
Root Cause	Technician received a shock from an improperly grounded magnet because procedures for design/ safety review were not followed	Technician received a shock from an improperly grounded magnet because there was inadequate supervision and oversight of the work, and a precursor event had not been reported

Table 4. Failure of Machining Arbor in Heavy Machine Shop

ORPS Occurrence	Failure of machining arbor in heavy machine shop	
Date	August 8, 2003	
Consequence	Near Miss/ Broken Arbor	
Direct Cause	Arbor shears at high rotating speed	
	Issue A	**Issue B**
Contributing Cause(s)	Horizontal cutting machine operating at 7500 RPM instead of 750 RPM	Tool design was inadequate (1” v. 2” stock)
Why?	1) Operator does not check program speed 2) Programmer inadvertently types extra zero in speed	1) No engineering of tool design 2) Failure to follow tool design Handbook guidance
Why?	1) Operator error 2) Programmer error	1) No requirement for engineering review 2) Job/schedule pressure
Causal Code(s)	3. Work Process Controls d. Work performance not within controls ▪ hazard controls not developed/implemented 5. Human Factors/Competency i. Inattention to detail	1. Planning and Organizing g. Methods to reach goals not determined ▪ Critical task not identified 2. Directing. Leading and Decision-making a. Inadequate management processes ▪ Inadequate scheduling
7 Deadly Sins	2. Placing scheduling considerations ahead of safety 1. Placing budgetary considerations ahead of safety 5. Ignorance, lack of fundamental knowledge/ tunnel vision/thinking inside the box	5. Ignorance, lack of fundamental knowledge/ tunnel vision/thinking inside the box 1. Placing budgetary considerations ahead of safety
Root Cause	The arbor sheared while rotating at ten times the intended speed because the programmer inadvertently keyed the wrong speed and the operator failed to verify the proper speed. The tool design was not adequately planned and implemented because of inadequate scheduling.	

Table 5. Forklift Load Strikes Overhead Lines

ORPS Occurrence	Forklift load strikes overhead lines	
Date	August 12, 2003	
Consequence	Backstay cable parted, pole leans over, cables sag to within 4 feet of road surface	
Direct Cause	Forklift mast contacts lower most cable	
	Issue A	**Issue B**
Contributing Cause(s)	No spotter	Forklift mast extends ~ 1 foot higher than lower most cable
Why?	Spotter stopped spotting to open rollup door	Inappropriate forklift used
Why?	Work was not properly planned	Clearance measurement not taken
Why?		JSA which requires "measure height of backrest extension to height of lowest overhead obstruction" was not followed.
Causal Code(s)	1. Planning and organizing f. Inadequate work organization ▪ Roles and responsibilities not defined or clear	3. Work process controls d. Work performance not within controls ▪ Original work plan (JSA) not followed
7 Deadly Sins	4. Overconfidence/Hubris	4. Overconfidence/Hubris
Root Cause	Roles and responsibilities of the spotter were not defined in the work plan, and the clearance measurement was not taken as required by the JSA	

Table 6. Railcar Movement While Loading

ORPS Occurrence	Railcar movement while loading	
Date	August 27, 2003	
Consequence	Near miss; unintended movement of rail cars	
Direct Cause	Added weight to railcar on incline exceeded rolling and/or braking friction	
	Issue A	**Issue B**
Contributing Cause(s)	Lead railcar wheels not chocked as required by JSA	Air brakes and manual brakes not set (Brakes inspected and functional?)
Why?	Only two chocks available for project, used elsewhere	JSA not followed for setting air and manual brakes
Why?	Insufficient number of chocks purchased for project.	
Why?	Inadequate job planning	
Why?		
Causal Code(s)	3. Work Process controls g. procedures not used or followed correctly ▪ unexpected results	
7 Deadly Sins	5. Ignorance, lack of fundamental knowledge/ tunnel vision/thinking inside the box	5. Ignorance, lack of fundamental knowledge/ tunnel vision/thinking inside the box
Root Cause	Since the job was not properly planned, there were not enough chocks available to follow the JSA, and the rail cars moved unintentionally	

Table 7. Defective North Face Air Purifying Respirator

ORPS Occurrence	Defective north face air purifying respirator	
Date	August 29, 2003	
Consequence	Defective Equipment	
Direct Cause	Removed mask without retaining bolts	
	Issue A	**Issue B**
Contributing Cause(s)	Bolts not replaced after masks were reassembled after cleaning	Inspection process failed
Why?	Chaotic work environment (i.e. work area, schedule, job assignments, overtime work)	No independent inspection done after reassembly
Why?	Job/schedule pressure to complete 200 respirators in a week	Procedure did not require independent inspection
Causal Code(s)	2. Directing, Leading and Decision Making c. Inadequate management oversight ▪ fragmented/inefficient operations 5. Human Factors/Competency b. Working environment issue ▪ Inefficient work	1. Planning and Organizing g. Methods to reach goals not determined ▪ Critical task not identified
7 Deadly Sins	2. Placing scheduling considerations ahead of safety	4. Overconfidence/Hubris 5. Ignorance, lack of fundamental knowledge/ tunnel vision/thinking inside the box
Root Cause	Respirators were reassembled without retaining bolts because of chaotic work environment that was not rectified by management or the workers; and an independent inspection was not performed after reassembly	

Table 8. Lifting Magnet Device Releases Steel Plate During Lift

ORPS Occurrence	Lifting magnet device releases steel plate during lift	
Date	September 4, 2003	
Consequence	Near Miss	
Direct Cause	Magnet releases plate	
Contributing Cause(s)	1) Failure to determine weight 2) Weight on drawing incorrect	
Why?	Magnetic force was insufficient to overcome the other forces acting on the plate (weight, off-center crane hook)	
	Issue A	**Issue B**
Why?	Plate weight exceeded rated capacity of magnet	Crane was not positioned directly over the hook attached to the magnet.
Why?	1) No independent calculation of weight 2) Weight marked incorrectly on drawing	Crane operator failed to follow training and procedures
Why?	1) Failure to follow basic crane operator procedure 2) Weight marked incorrectly on drawing	
Why?	2) Neither one of the five signatories on the CAD drawing independently verified the weight	
Causal Code(s)	3. Work process controls g. Procedures not used or followed correctly ▪ Unexpected result 3. Work process controls b. Design Implementation Process Inadequate ▪ Design Verification inadequate	3. Work process controls g. Procedures not used or followed correctly ▪ Unexpected result
7 Deadly Sins	4. Overconfidence/Hubris 5. Ignorance, lack of fundamental knowledge/ tunnel vision/thinking inside the box	4. Overconfidence/Hubris
Root Cause	An under-rated lifting magnet was used because the weight of the plate was not independently calculated by the operator (per crane operator training) nor verified by the drawing signatories, and an additional lateral force was applied to the magnet because the operator failed to follow the procedure for positioning the crane directly over the magnet.	

Table 9. Injury to Hand While Operating Lathe

ORPS Occurrence	Injury to hand while operating lathe	
Date	September 4, 2003	
Consequence	Injured hand	
Direct Cause	Hand slips off lathe speed control lever into path of 13” bent, extended, unsupported whirling tube stock	
Contributing Cause(s)	1) Defective machine design 2) Failure to use stop button 3) Lack of Feedback on speed	
	Issue A	**Issue B**
Why?	Operator realized high speed was inadvertently selected and jerked lever to low speed position to correct	Tube stock bent at high speed due to rotating instability
Why?	Operator inadvertently selects high speed	1) Speed was too high 2) Stock was unsupported
Why?	1) Machine design defective 2) Operator Inattention	2) No formal procedure requires support, but skill of the craft expertise would recognize the need for support
Causal Code(s)	3. Human Factors/Competency a. Human-machine Interface Problem ▪ Unanticipated results 5. Human Factors/Competency i. Inattention to detail	3. Work Process Controls d. Work performance not within controls ▪ Hazard controls not developed/implemented
7 Deadly Sins	5. Ignorance, lack of fundamental knowledge/ tunnel vision/thinking inside the box 5. Ignorance, lack of fundamental knowledge/ tunnel vision/thinking inside the box	4. Overconfidence/Hubris 4. Overconfidence/Hubris
Root Cause	An extended piece of tubing, for which a hazard control had not been developed nor implemented, struck the operator’s hand as a result of switching the lathe to a low speed after inadvertently selecting an inappropriate high speed on a poor ergonomic machine design.	

Table 10. Graduate Student Incurs Laser Injury To Eyes

ORPS Occurrence	Graduate student incurs laser injury to eyes	
Date	September 9, 2003	
Consequence	Eye injuries	
Direct Cause	Harmful energies of laser light entering graduate student's eyes	
Contributing Cause(s)	1) Neither post doc nor graduate student fully understood the danger 2) Chemistry Department Management placed burden of documentation on PI without verifying its completeness 3) Laser was installed and operated without registration and review by the LSO 4) PI failed to include PAL in required posting and documentation 5) Management of laser activities at BNL did not ensure the LSO was performing his duties in compliance with the Laser Safety Subject Area	
	Issue A	**Issue B**
Why?	Selected energy level too high	Student did not realize the potential for harm Proper eyewear not worn Student did not understand procedure employed by the PI the previous day
	Approvals of laser configurations and installations are not being completed by the LSO	Chemistry Department is not ensuring that students fully appreciate the laser hazards present in the laboratory nor understand their obligation to use stop work authority
Why?	The new LSC was not fully aware of his roles and responsibilities	Required documentation is not being completed in a timely manner and required training is not being completed
Why?	The Chemistry Department has not defined the role of the Laser Safety Coordinator	There is no documentation of system-specific training
Causal Code(s)	1. Planning and Organizing f. Inadequate Work Organization ▪ Roles and Responsibilities Not Defined or Clear	3. Work Process Controls g. Procedures Not Used or Followed Correctly ▪ Unexpected results 4. Human Factors/Competency h. Competence Not Commensurate with Responsibilities ▪ Appropriate Qualified and Competent Personnel Not Assigned to Work n. Training Deficiency ▪ Inadequate Training Content/Materials
7 Deadly Sins	5. Ignorance, lack of fundamental knowledge/ tunnel vision/thinking inside the box 2. Placing scheduling considerations ahead of safety	4. Overconfidence/Hubris 5. Ignorance, lack of fundamental knowledge/ tunnel vision/thinking inside the box
Root Cause	Personnel failure to follow established rules and procedures for the laboratory, and Management/supervisor failure to ensure that graduate student was completely and properly trained and understood established rules	

Table 11. Elevator Oil Line Breaks During Preliminary Acceptance Testing

ORPS Occurrence	Elevator oil line breaks during preliminary acceptance testing
Date	September 10, 2003
Consequence	80 gallons of hydraulic oil was released into the ground.
Direct Cause	The pipe between the pump and the jack failed, thereby permitting the uncontrolled release of the oil into the ground
Contributing Cause(s)	1) Elevator piping in ground 2) In ground piping not included in scope of work or hazard analysis
Why?	Pipe apparently failed (pipe was not dug up to verify because it would destabilize the foundation to do so) due to age or condition (Installed in ground under slab in 1964) while in ground
Why?	Pipe not included in project scope or hazard analysis
Causal Code(s)	3. Work Process Controls a. Scope of work not (adequately) defined c. Hazards not identified/analyzed
7 Deadly Sins	5. Ignorance, lack of fundamental knowledge/ tunnel vision/thinking inside the box
Root Cause	Hydraulic oil released during elevator acceptance testing because the entire pump/piping system was not considered in the scope of work nor the hazards analysis

E. Common Causes for the Ten ORPS Occurrences

The results of the Causal Analysis of the ten ORPS Occurrences are provided in Table 12. In all cases, there was more than one factor that caused or contributed to the cause of the Occurrences. The result is multiple causal factors for the Occurrences, which is why only ten Occurrences result in 29 Causal Codes. The single most significant common cause was found to be a failure of Work Process Controls. What this means is work is not being planned or thought out by the people involved in the Occurrence, either directly or indirectly, hazards are not being considered or addressed, or training, procedures, or Laboratory Standards are being ignored. If one combines Codes **2 - Directing, Leading, and Decision-Making** and **5 – Human Factors/ Competency**, we have a second significant common cause, wherein workers and/or management are not doing their job adequately or are not taking the necessary time to understand the task at hand.

Table 12. Summary of Analysis by Battelle Causal Categories

Causal Category	# of Instances
1. Planning and Organizing	**3**
f. Inadequate Work Organization	1
g. Methods to Reach Goals Not Determined	2
2. Directing, Leading, and Decision-Making	**5**
a. Inadequate Management Processes	2
b. Inadequate Supervision	1
c. Inadequate Management Oversight	2
3. Work Process Controls	**13**
a. Scope of Work Not Defined	2
b. Design Implementation Process Inadequate	2
c. Hazards Not Identified/Analyzed	2
d. Work Performance Not Within Controls	4
g. Procedures Not Used or Followed Correctly	3
4. Feedback and Improvement	**1**
a. Self-Assessment and Performance Measurement Not Adequate	1
5. Human Factors/Competency	**7**
b. Working Environment Issue	1
f. Poor Judgment	1
h. Verbal or Written Communication Problem	1
i. Inattention to Detail	3
k. Unfamiliar Application	1

The results of the "7 Deadly Sins" Analysis of the ten ORPS Occurrences are provided in Table 13. As explained above, there was more than one factor that caused or contributed to the cause of the Occurrences; hence, there are more than ten of the "7 Deadly Sins" factors in the summary. There are two predominant factors that account for the great majority of the Occurrences - **Overconfidence/Hubris** and **Ignorance, lack of fundamental knowledge/tunnel vision/thinking inside the box**. This suggests that people are deliberately ignoring standards, procedures and/or good and accepted safe practice, or they are assuming someone else is taking care of safety and aren't bothering to find out if that is true.

Table 13. Summary of Analysis by "7 Deadly Sins" Factors

"7 Deadly Sins"	# of Instances
1 Placing budgetary considerations ahead of safety	2
2. Placing scheduling considerations ahead of safety	7
3. Political considerations	0
4. Overconfidence/Hubris	13
5. Ignorance, lack of fundamental knowledge/ tunnel vision/thinking inside the box	14
6. Sense of entitlement	1
7. Apathy resulting from lack of empowerment	0

This summary overwhelmingly demonstrates that workers, supervisors and managers involved, either directly or indirectly, in these Occurrences do not place enough emphasis on planning and doing work safely and following procedures/standards. This is not isolated to just one group or department.

The causal analysis performed by the Task Force also identified instances where the event occurred because hazard controls were not developed, a critical task was not defined, roles and responsibilities were not defined or clear, or the scope of work was not adequately defined. More specifically, work that may have been thought to be "skill-of-the-craft" was actually non-routine or went outside the expected realm of experience and expertise. Skill-of-the-craft is defined as routine work activities that are within the expected realm of experience and expertise of a rationally thinking and properly trained person and can be done safely without additional work planning and oversight. Managers at BNL need to fully understand the scope of work required before making a skill-of-the-craft determination, and encourage workers to report back when conditions are non-routine or outside the expected realm of experience and expertise. Managers should also more closely examine activities among their skill-of-the-craft employees to determine if risky work practices are exposing workers to hazardous conditions. This is particularly of concern when unexpected field conditions are encountered. Workers should understand the limits of their expertise and not hesitate to seek additional guidance.

III. Safety Databases and Trends

A. Background

The Task Force also was charged to determine if there are common causes indicative of an underlying breakdown in BNL's management systems, and to perform any needed analysis to determine if a programmatic breakdown exists. The Task Force began looking at the ORPS history for several years, and expanded the investigation to include all related management systems. These systems are the Occurrence Reporting and Processing System (ORPS), the Occupational Safety Management Information System (OSMIS), the Computerized Accident/ Incident Reporting System (CAIRS) and the Radiological Awareness Reports (RAR). Ultimately, some Human Resources data were requested for investigation. For several meetings, as data were evaluated, more questions arose requiring further investigation and evaluation. The critical questions relevant to the Task Force's charge were answered, but several other questions could not be concluded with the time and resources available.

The Task Force began looking at ORPS and OSMIS data immediately. There were many years of data available, and the Task Force needed to focus on reliable data for a consistent time period for all of the data sources. The Task Force elected to review the data for whole calendar years beginning with 1998, primarily because that was the first whole year for which all data sources were available.

The Task Force also explored some intangible elements that could cause or contribute to the incidents at BNL. This is sometimes known as "What-if" analysis. In this technique, a potential cause is postulated, and an investigation is conducted to prove or disprove the postulation.

It became readily apparent at the very beginning of this effort that BNL does not have safety management ***information*** systems. There are several ***data*** systems available, but these are not configured to provide the ***information*** necessary to discover and evaluate trends. Much of the Task Force's effort was spent capturing data and developing it into useful information. Thus, it is easy to arrive at the first finding of the Task Force, that there is a breakdown in BNL's Safety Management Systems. It also became apparent early on that the depth and breadth of the investigations varied widely, and the ORPS classifications were susceptible to some subjectivity. This factor makes it difficult to trend data because the data may not be correct or at least held to some standard of quality. This was identified during the re-analysis of the ten ORPS Occurrences that triggered this investigation.

The following is a discussion of the data systems used in our investigation and the evaluations made using these data.

B. Occurrence Reporting and Processing System (ORPS)

The ORPS captures information on the discovery, response, notification, investigation, and reporting of occurrences to BNL and DOE management. ORPS applies to abnormal events or conditions that may:

- Endanger the health and safety of staff or the public,
- Have an adverse effect on the environment,
- Seriously impact the operations and intended purpose of BNL facilities,

- Result in loss or damage of property, or
- Adversely affect national security or the security interest of DOE or BNL.

When an abnormal event or condition is reported, it is relayed to an Occurrence Categorizer who determines if the event or condition meets the criteria for a Reportable Occurrence. The Occurrence Category drives a graded approach to the level of follow-up actions required for internal and external notifications, occurrence investigation and analysis, and occurrence reporting. After a Reportable Occurrence is categorized and appropriate notifications are made, it is evaluated to assess its significance and programmatic impact, causal factors, generic implications, and the need for, and implementation of, corrective actions. The information identified in that process forms the basis for the Final Occurrence Report. This information also assists in improving policies and procedures and communicating lessons learned.[1]

The first step in our investigation was to determine whether the apparent spike in ORPS Occurrences experienced in the third calendar quarter was unusual. Figure 1 is the ORPS Occurrence rate by calendar quarter for the period 1998 – Third Quarter 2003, and shows the ORPS Occurrence rate is steadily decreasing over the time period. It also shows that the rate is increasing in 2003. The data plotted for the third quarter of 2003 only included the reports up to September 10, so it is clear that the third quarter, if unchecked, would exceed the rate for the second quarter, thereby showing a steady increase in the rate for 2003.

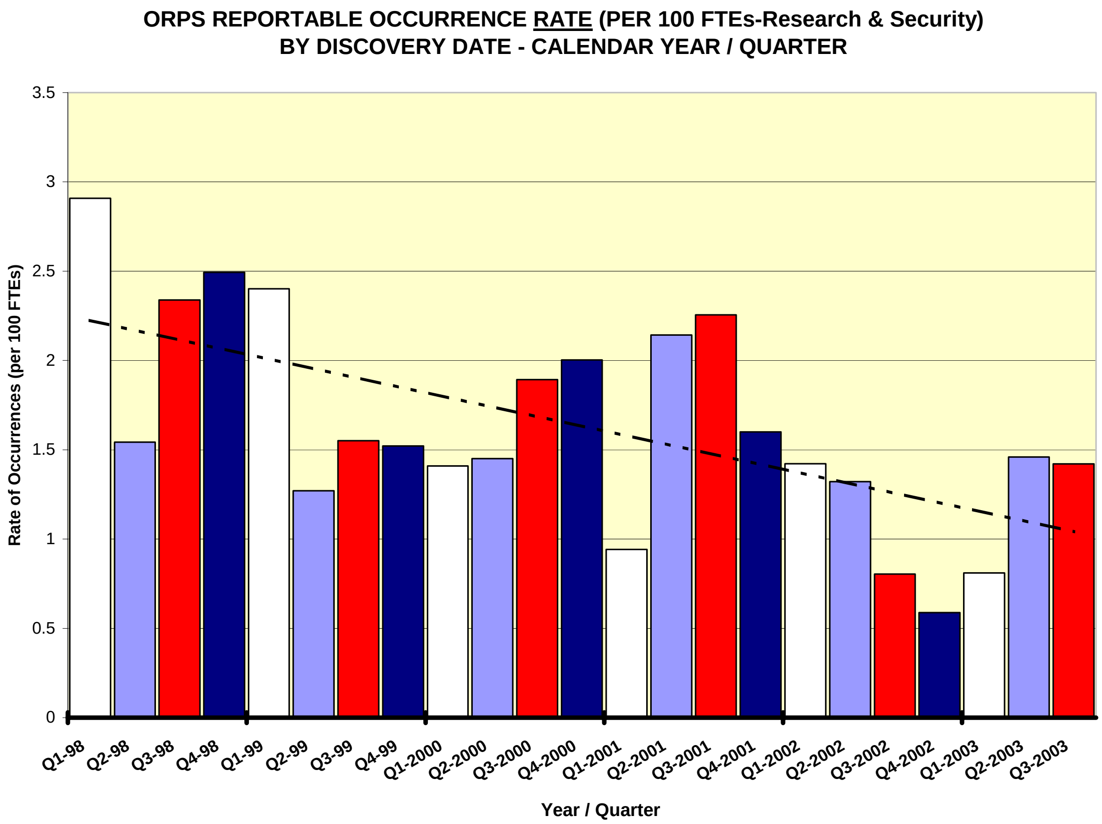


Figure 1. ORPS Reportable Occurrence Rate

[1] Background taken from https://sbms.bnl.gov/standard/20/2000i011.htm

The Task Force also evaluated the possibility that the third calendar quarter may be a "peak" quarter for incidents at BNL. It was opined that it was the end of the fiscal year, so more work was being done to close out funds. Some capital projects are executed in the August-September time period because additional funds are available or must be spent before the end of the fiscal year. Finally, it was opined that more people would be taking vacation, putting additional "stress" on the workers that did not. Figure 2 is a plot of the Occurrences by quarter, consolidated for the period studied. While the third quarter is slightly higher, it is not statistically significantly higher than the other quarters. Again, looking at Figure 1, the third quarter, when normalized to rate by hours worked, shows that the third quarter is not always the highest quarter for ORPS Occurrences. The reader is reminded that the fourth quarter in Figure 2 does not have the fourth quarter of 2003, but would scale to approximately the same as the other quarters. Further discussion regarding the amount of time worked in the third quarter versus other quarters is contained in the section on Human Resources data.

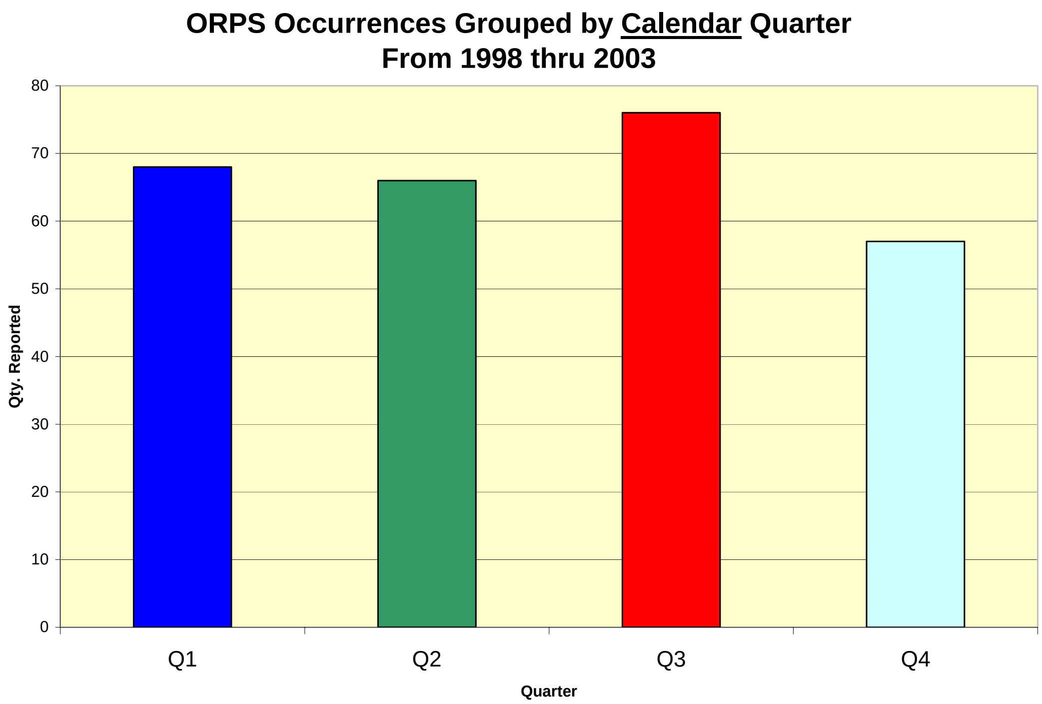


Figure 2. ORPS Occurrences, by Calendar Quarter

The Task Force also evaluated the number of ORPS Occurrences for each department/division to determine whether there were any chronic offenders. This effort was hampered by the flux in departments within BNL during the past six years. Departments and divisions were being created, consolidated and eliminated, sometimes with one or more departments "morphing" into another. Figure 3 shows the ORPS Reportable Occurrences for the past three years, by Department/ Division, in Pareto format. The Task Force was surprised to see some relatively small Departments/ Divisions, who should have relatively low exposure, appear, specifically the Medical and Chemistry Departments. This Figure shows that nine Departments/Divisions account for 83% of the ORPS Reportable Occurrences at BNL. The "Other" category is the consolidation of the ORPS Reportable Occurrences for 19 Departments/Divisions whose individual quantities were low in comparison to the other nine. This was further evaluated in Figure 4 and Figure 5. Again, when the data were normalized to rates, The Medical and Chemistry Departments have the highest rates for Scientific Departments. The Figures also show that the Departments/Divisions performing environmental clean-up work have the highest ORPS Occurrence rates at BNL.

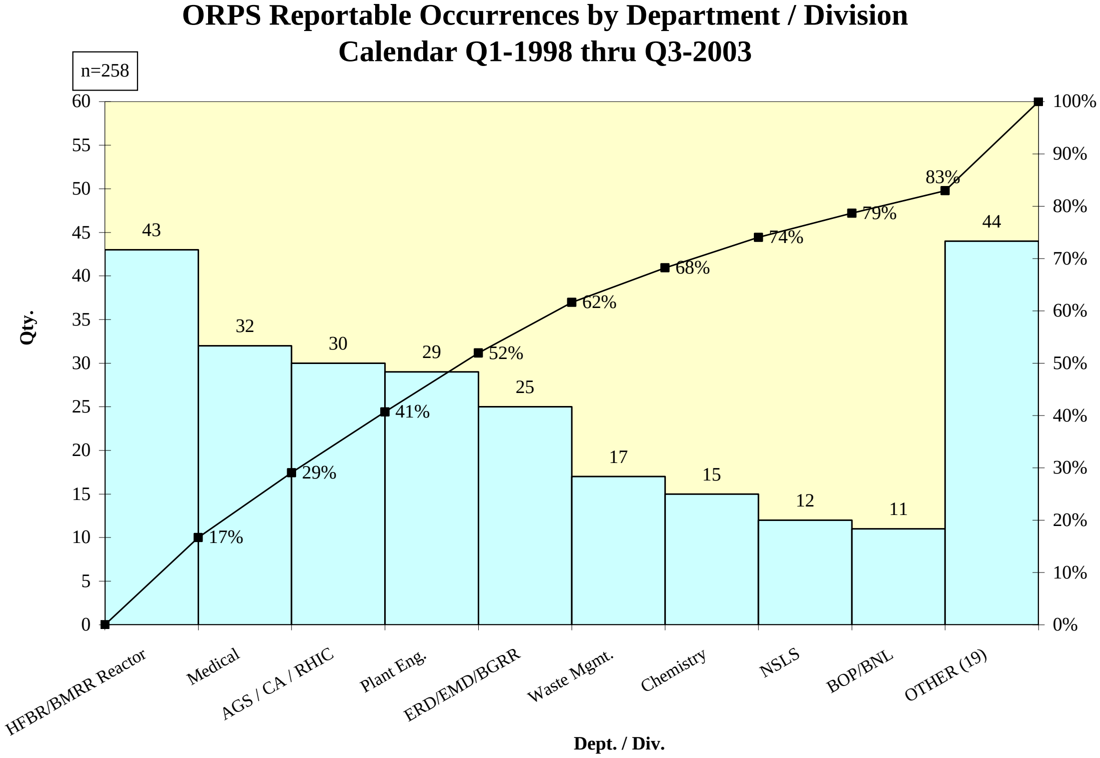


Figure 3. Pareto Chart of ORPS Occurrences by Department/Division

There was some discussion by the Task Force regarding the depth of the analysis of the ORPS Occurrences. Figure 6 shows the ***total*** number of reports submitted to the ORPS Coordinator. One may see that the number of ***reportable*** Occurrences is a smaller percentage of the total number of reports. The Task Force began a review of the ***unreportable*** Occurrences, but the task proved too onerous for the time period allotted. There may be something to be gained from a review of these reports, or a review to determine whether the classification as unreportable is uniformly applied, but that effort is beyond the scope of this Task Force.

The Task Force also investigated whether the incidents, or rise in incidents, could be attributed to worker fatigue. As discussed above, there was some thought that decreasing numbers of employees, decreasing budgets, and vacations occurring during the third calendar quarter would cause workers to be working longer hours, and that their fatigue increased the incident rates. It was speculated that errors resulting from this fatigue would be greatest late in the day. To evaluate this, Figure 7 was developed. It appears from this Figure that the rise in incidents is not from worker fatigue due to excess hours worked. The great majority of incidents are reported during the period 1400–1600 (2-4 p.m.), and the majority of the incidents are discovered during daytime working hours. It was the Task Force's conclusion that the Occurrences do not appear to be occurring overnight because there was no spike in discovery time during the period 0800 – 1000, when the workday starts and overnight incidents would most likely be discovered.

However, the information systems did not contain the time of occurrence. The information captured is time of discovery.

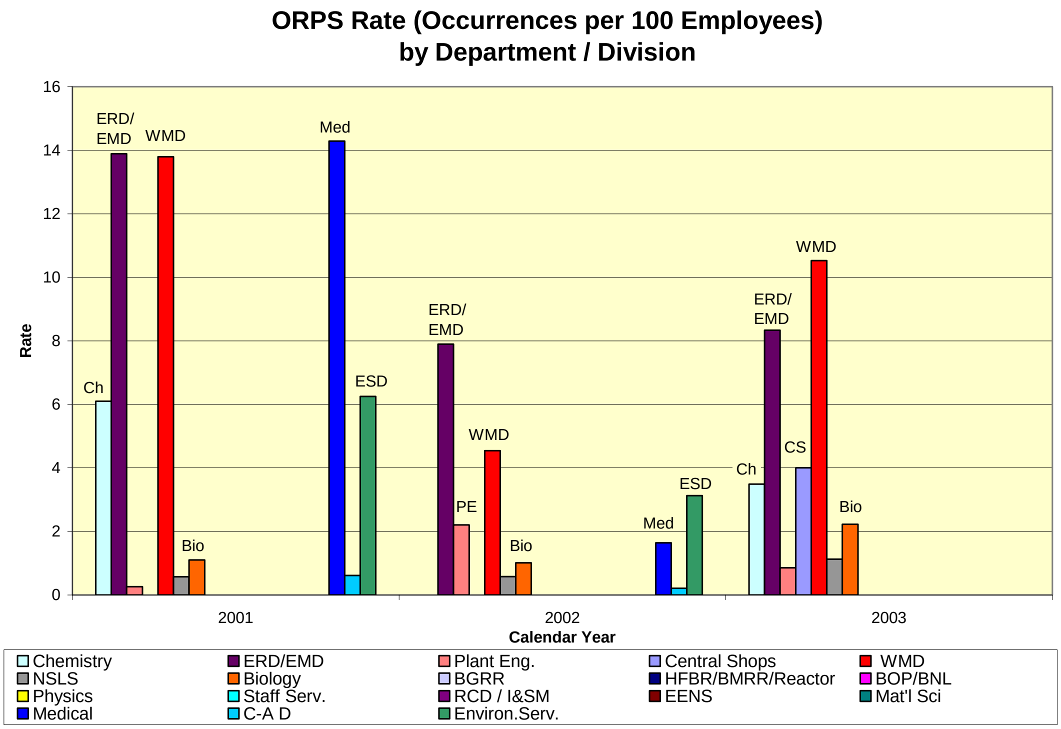


Figure 4. ORPS Rate by Department/Division for 2001 - 2003

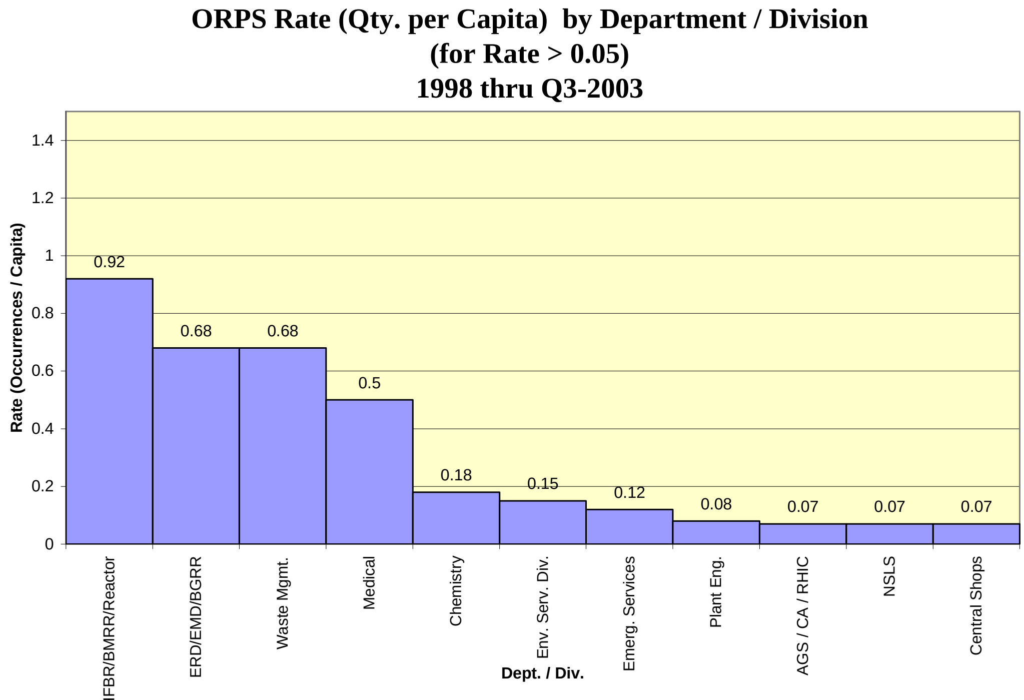


Figure 5. ORPS Rate by Department/Division for Rates >0.05

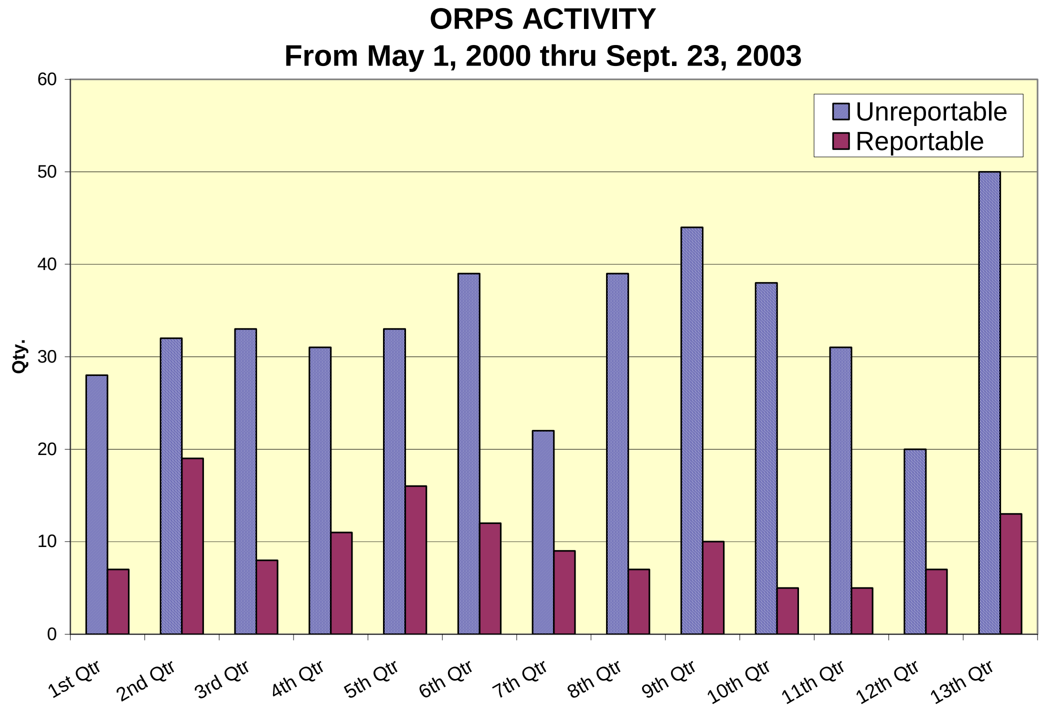


Figure 6. ORPS Activity from May 2000 through September 2003

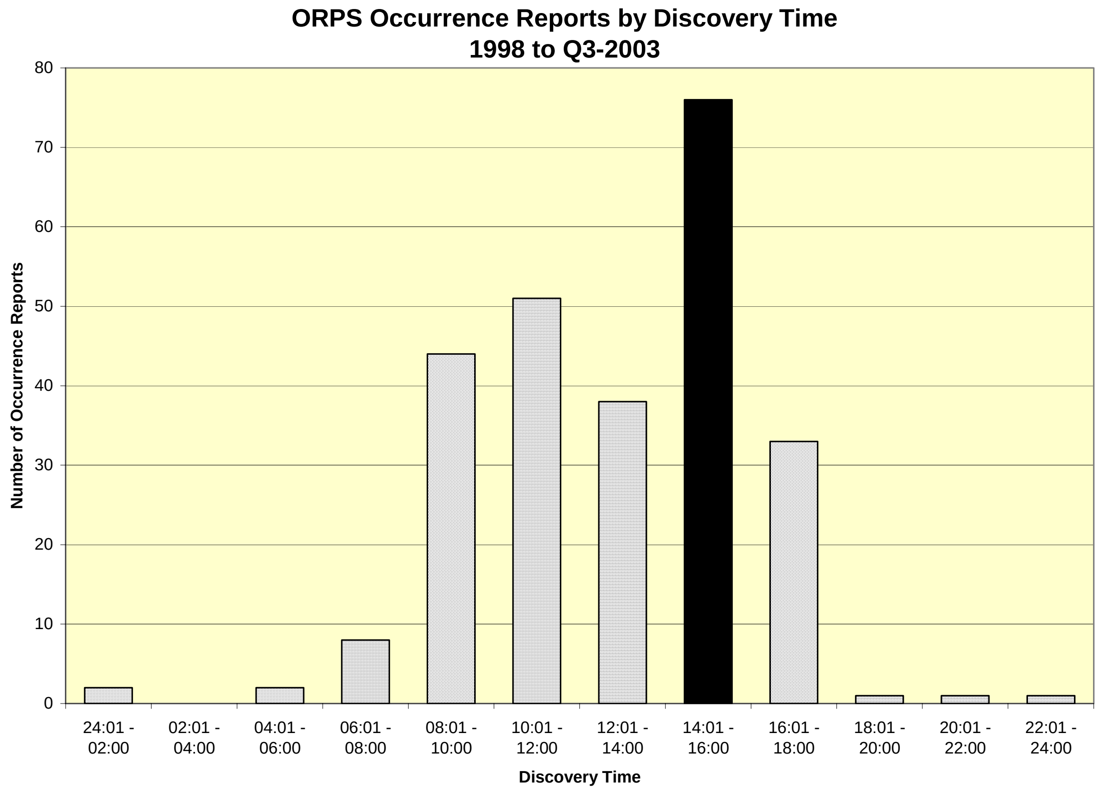


Figure 7. ORPS Occurrences by Discovery Time

The Task Force deliberated over the work-hours issue for several meetings because they wanted to be sure the potential for worker fatigue or schedule pressures was thoroughly evaluated. Figure 8 plots both the number of ORPS Occurrences and the ORPS Occurrence rate. The number of occurrences is divided by ten in the plot in order to have the line scale with the rate. The rate is per 100 full-time employees (FTEs), which is the same type of rate that the Occupational Safety and Health Administration (OSHA) uses (200,000 hours). With the exception of Q4-2000 and Q3-2001, the data plot along the same lines. This indicates that the number of occurrences is not adversely affected by more work hours. Therefore, worker fatigue or schedule pressures do not appear to be an underlying factor in ORPS Occurrences at BNL. Also note on this Figure that the ORPS Occurrences, however they are measured, are increasing consistently since their low during Q4-2002.

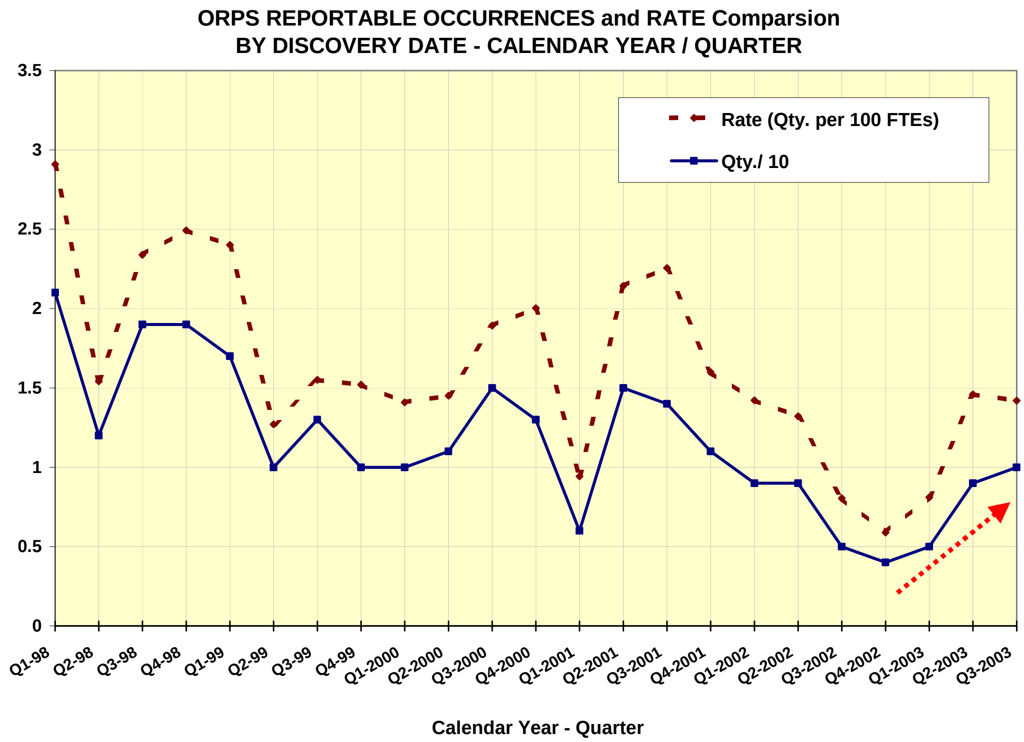


Figure 8. ORPS Occurrences and Rates, Normalized

Finally, the Task Force looked at ORPS Occurrences and injuries (OSMIS) to see if those data correlate. This is shown in Figure 9. This Figure shows that the trends for both types are continuing down for the period reviewed. In that respect, the data do correlate. However, one can see that the injuries have a greater cyclical frequency than the Occurrences. Also, the injuries sometimes are out of sync with Occurrences. This is shown in Q4-98, Q1-2000, Q1-2001, and Q3-2002. The injury data and its characteristics are discussed in greater detail in the next section.

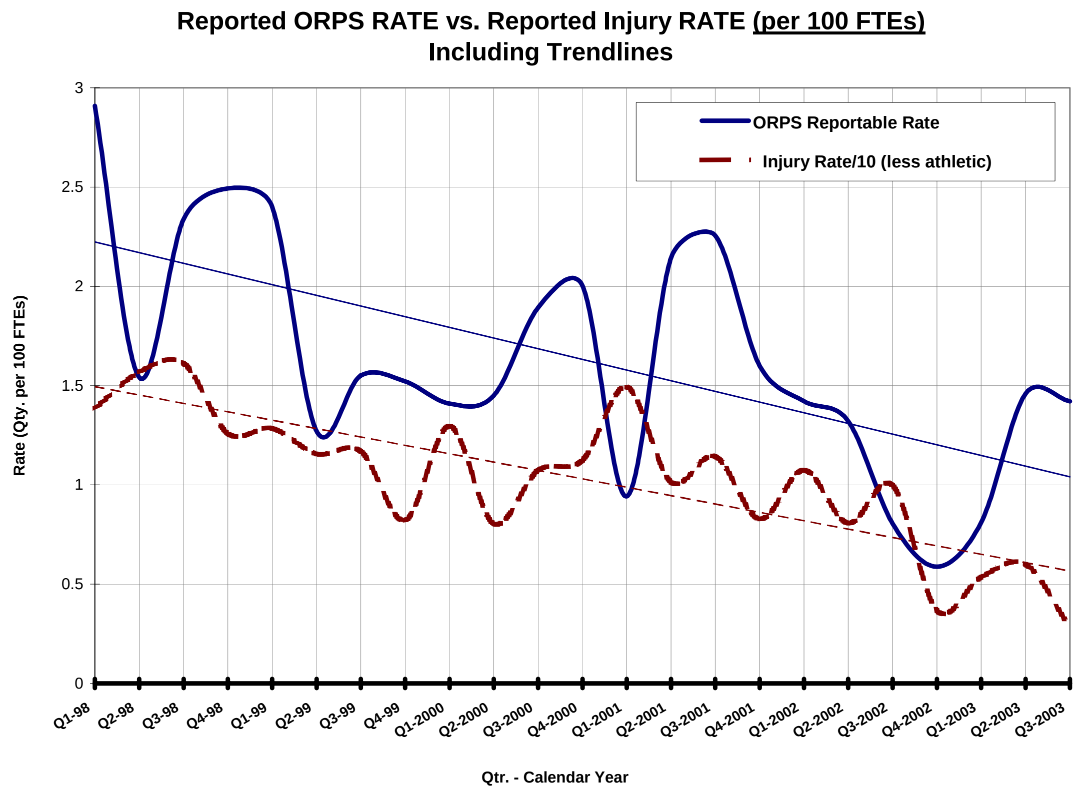


Figure 9. ORPS Rate and Injury Rate, with Trend Lines

C. Occupational Safety Management Information System (OSMIS)

The Occupational Safety Management Information System (OSMIS) dates back to the late 1980s, but has undergone several revisions. The latest revision occurred this past year, when it was decided to go with the Compliance Suite program. That program has only covered occupational injury data back to January 1, 1997.

The new program enables a wide variety of sorting and tracking reports, which have proven useful. Information collected can now incorporate many sorting and trending features, depending on how thorough the investigation of the incident was. By the end of this calendar year it will have an electronic investigation report, which will be tied directly to the data fields in the OSMIS database.

OSMIS uses employee data and work hour data directly from PeopleSoft and collects information pertaining directly to the incident, specific injury/illness, near miss, medical diagnoses, medical provider, transportation and treatment information, workers' compensation information, lost and restricted time information, primary and secondary hazard information, corrective action information, personal protective equipment (PPE), related cost information, and other additional narrative fields. OSMIS also originally was created to generate CAIRS reports. However, this is no longer the case because BNL is required to enter the case information directly into the CAIRS database system.

The OSMIS database contains all reported injuries at BNL, including athletic injuries. Athletic injuries are classified as injuries occurring during athletic events or activities at lunchtime or after work during BNL hosted or sponsored events. These injuries were excluded from the Task Force's review of injuries at BNL because they were not directly work related. They are, however, work-related activities that are reportable under Worker's Compensation.

The Task Force began its investigation of OSMIS data by examining the injury rates by calendar quarter. These data are shown in Figure 10. As with the ORPS data, injury rate is steadily declining over the six-year period reviewed by the Task Force. Also indicated is that the third calendar quarter is not statistically significantly higher than the other quarters. Rate data, as concluded with the ORPS, indicates that the injuries are not a function of worker fatigue or schedule pressure.

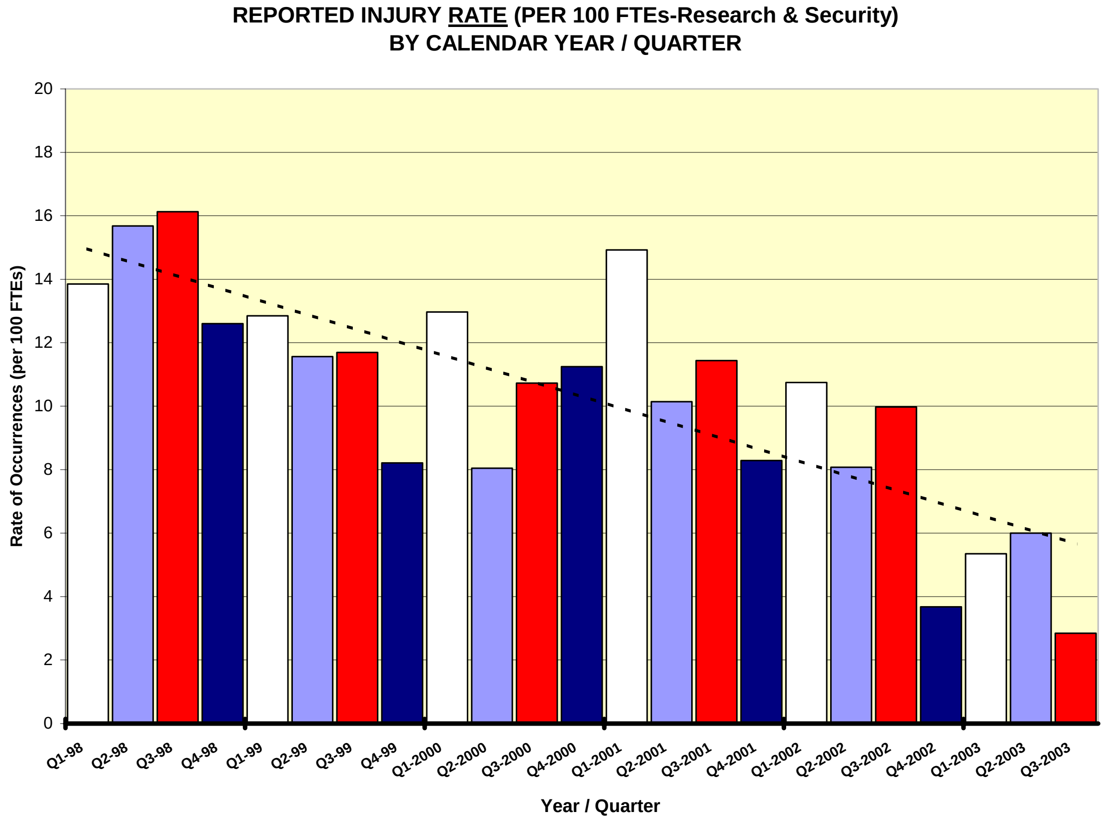


Figure 10. Reported Injury Rate, by Calendar Quarter

The Task Force investigated the injuries by job types in order to determine whether a particular job type was over-represented in the data. Figure 11 is a Pareto graph showing the results of this investigation. The data had to be consolidated because the job types were too finely categorized. As an example, Technician is the term used for most manual workers in the scientific departments, and is rather uniformly used. However, the manual workers in non-scientific organizations are mostly union employees, and are categorized by trade. At first, the data indicated that Technicians were over-represented in the data. Once the trades were consolidated, however, their combined injuries were more inline with their scientific department equivalents, Technicians. Other categories that were combined are shown in upper case.

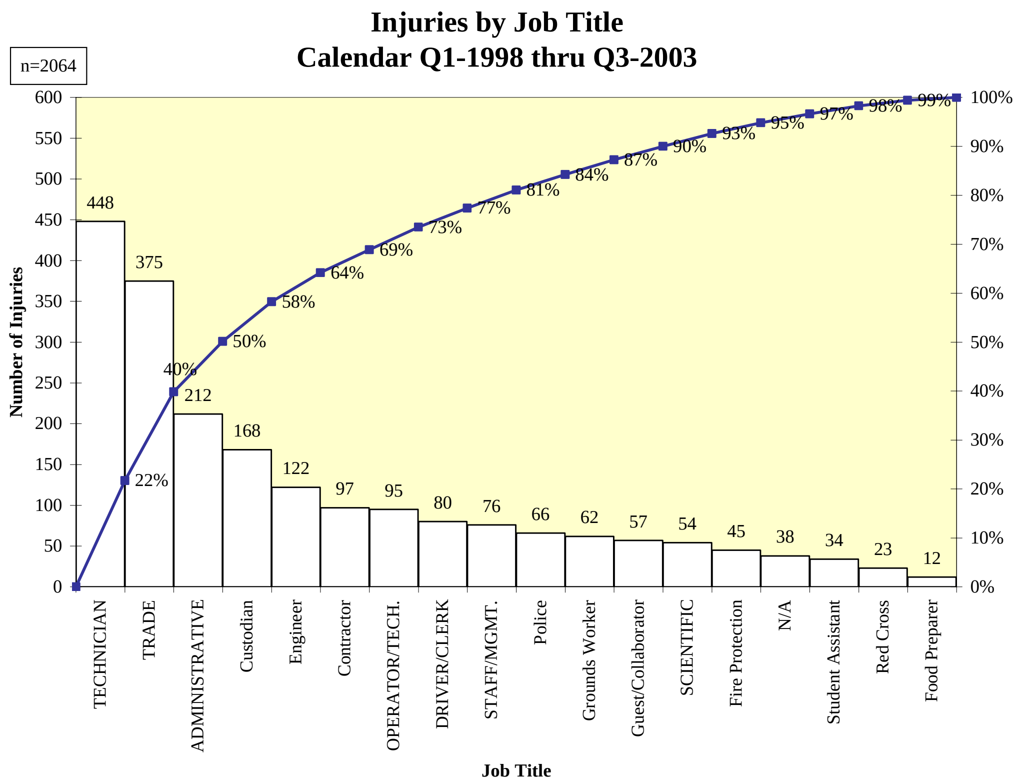


Figure 11. Injuries by Job Title

There are a few other observations worthy of note. Guests and Collaborators are being injured while here at the laboratory more often than their scientific employee counterparts. This may mean that our Guests and Collaborators are not being trained and/or supervised adequately while here at BNL. The same observation is made for the category Student Assistant. Red Cross warrants explanation, because they have their own category and because they average four injuries per year. The Red Cross has a facility here at BNL, a kitchen, hosted by the Medical Department. These kitchen workers are not BNL employees. Again, visitors to BNL that are not BNL employees are being injured here. And while they operate a kitchen, they have had twice as many injuries for the timeframe studied as professional Food Preparers also working here at BNL. Finally, the Task Force observes there were 38 injuries for which there is no job classification. This would indicate that the data capture for this management system is not adequate, and another indication that the safety management systems at BNL are not working.

The Task Force examined the Technician injuries to determine whether there was an increased risk to these workers. Figure 12 shows the Technician injuries by injury type. Nearly two-thirds of the injuries to Technicians, 64%, are attributed to Overexertion, Struck by Object, and Contact with Sharp Edge. While the last two are specific enough to understand, the first, Overexertion, is not so easy to understand. It was suggested that Overexertion could be strains/sprains, particularly of the back, but there was not enough time to pursue this investigation. The Task Force notes that Overexertion injuries may be indicative of ergonomic issues at BNL or an aging workforce, and warrants further investigation.

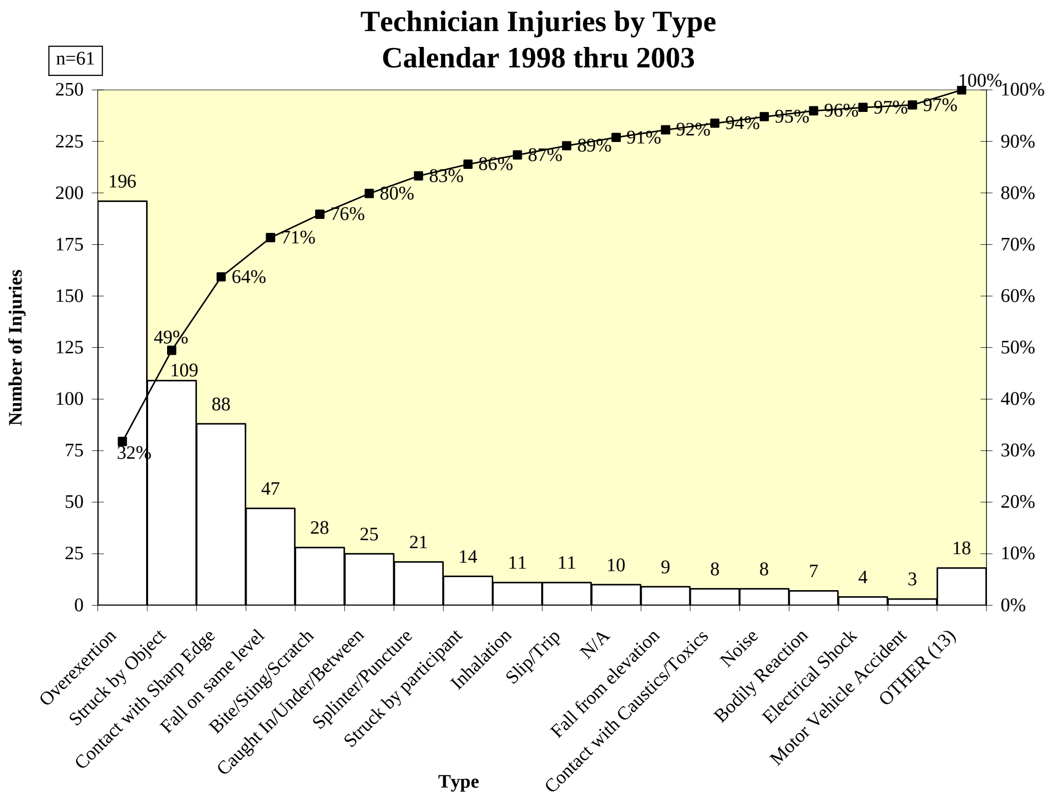


Figure 12. Technician Injuries by Type

Further examination of these injury data provides a striking pattern. The third and fifth highest number of injuries at BNL are white-collar jobs. These are Administrative and Engineer. Combined, they account for 16% of the injuries at BNL. The Task Force began an investigation into these injuries to determine whether there is a particular exposure that would account for this alarming trend. Figure 13 and Figure 14 show the Injury Types for these Job Categories. As with the Technicians, nearly two-thirds of the injuries, 66% of Administrative injuries and 64% of Engineer injuries, are attributed to Falls from Same Level, Overexertion, and Struck by Object. Falls and Overexertion equally afflict the Administrative job category, while Overexertion is the single greatest issue for Engineers. Finally, Figure 15 shows the injury type for all injuries over the period studied. Overexertion accounts for 26% of all injuries, and is the single greatest injury type at BNL. It is suggested by the Task Force that the overexertion injuries may reflect either ergonomic issues or are characteristics of an aging workforce, but the Task Force did not have sufficient time nor charge to investigate further. Clearly, these issues should be investigated further.

The Task Force attempted to normalize these data to injury rate, but the OSMIS job categories do not correlate directly with the BNL job categories maintained by the Human Resources Division. In fact, there are over 700 different job titles used, with some only lasting one year. This is discussed further in the section on Human Resources data. Suffice to say that this is another issue with the BNL Safety Management Systems.

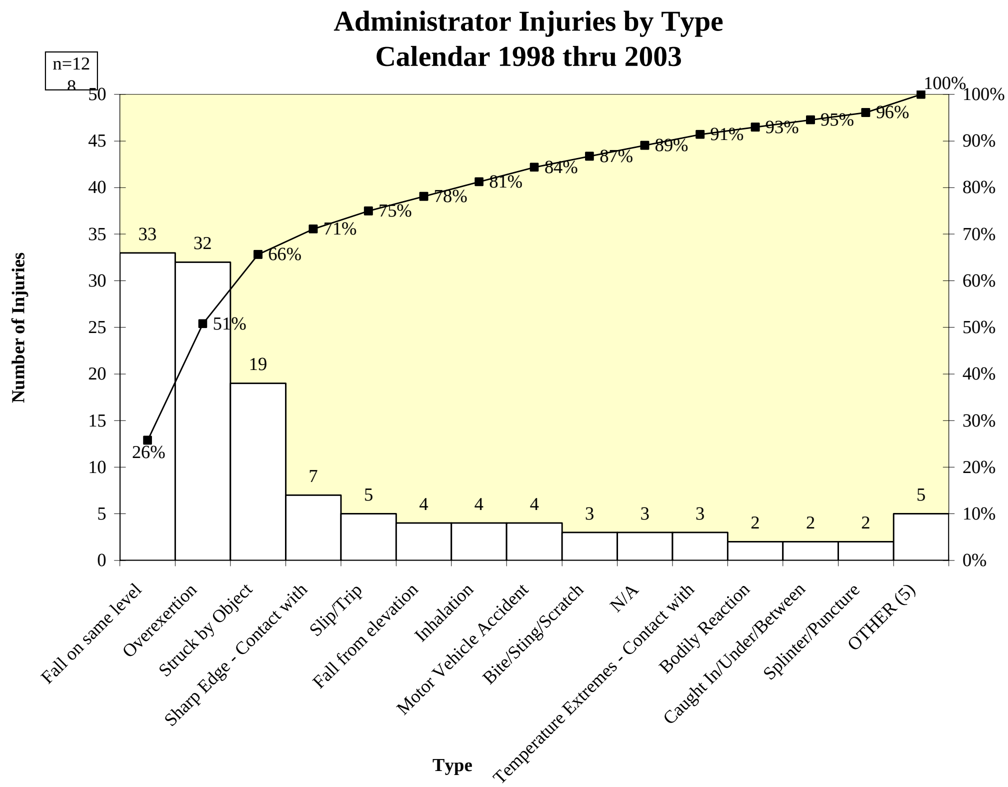


Figure 13. Administrator Injuries by Type

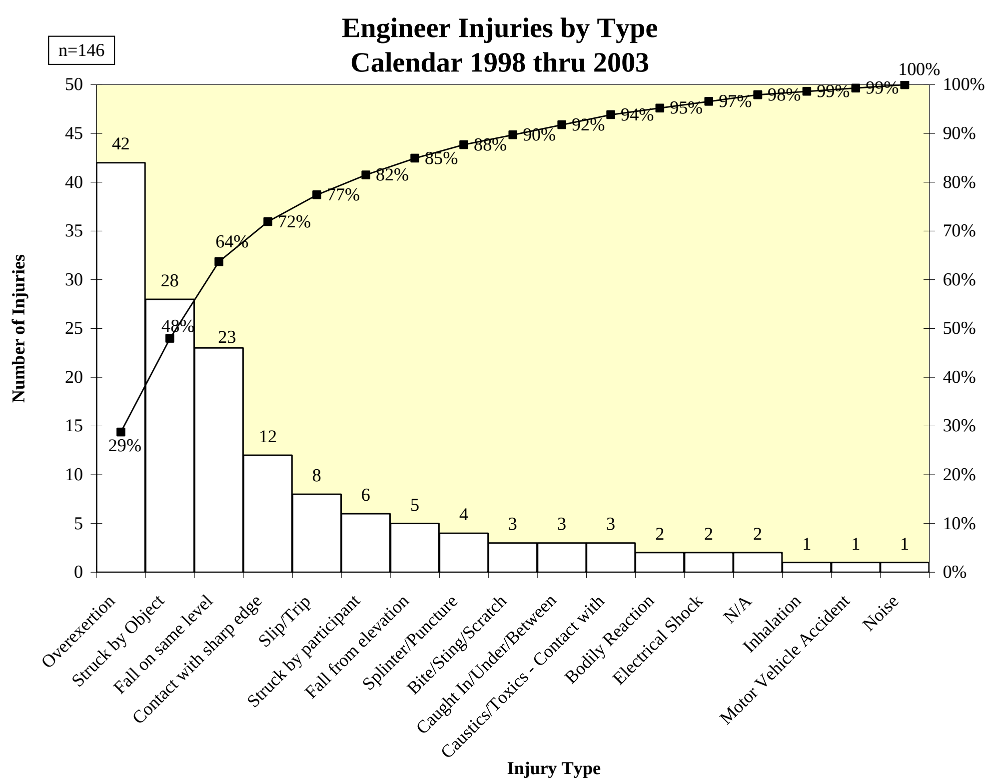


Figure 14. Engineer Injuries by Type

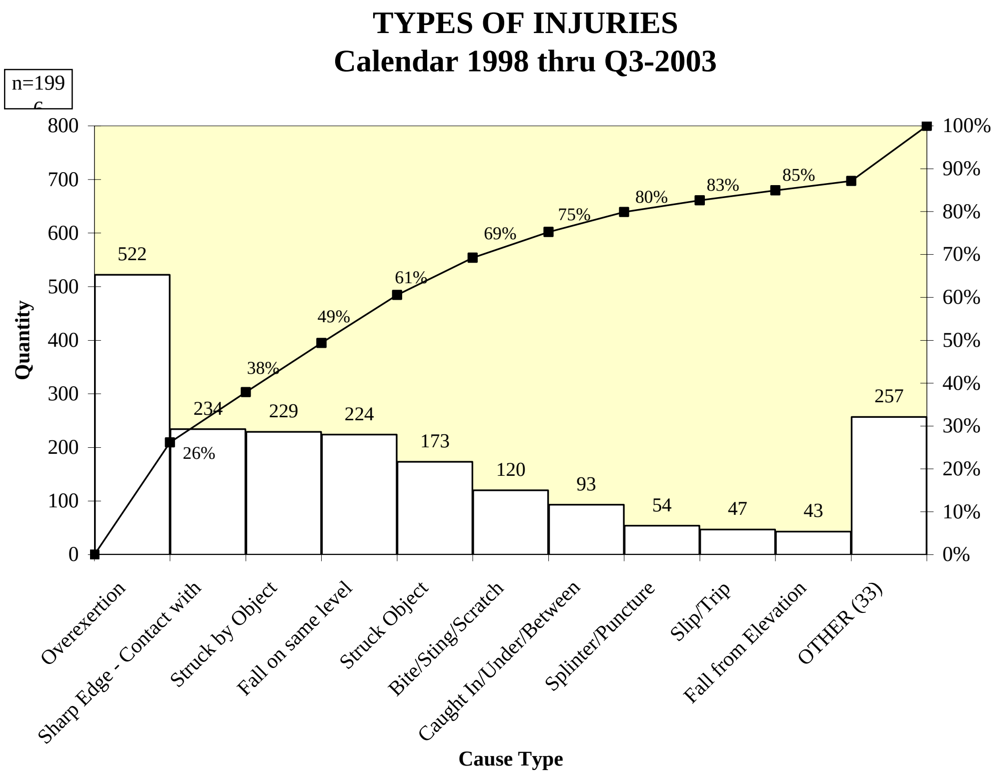


Figure 15. Injuries by Type, for All Injuries

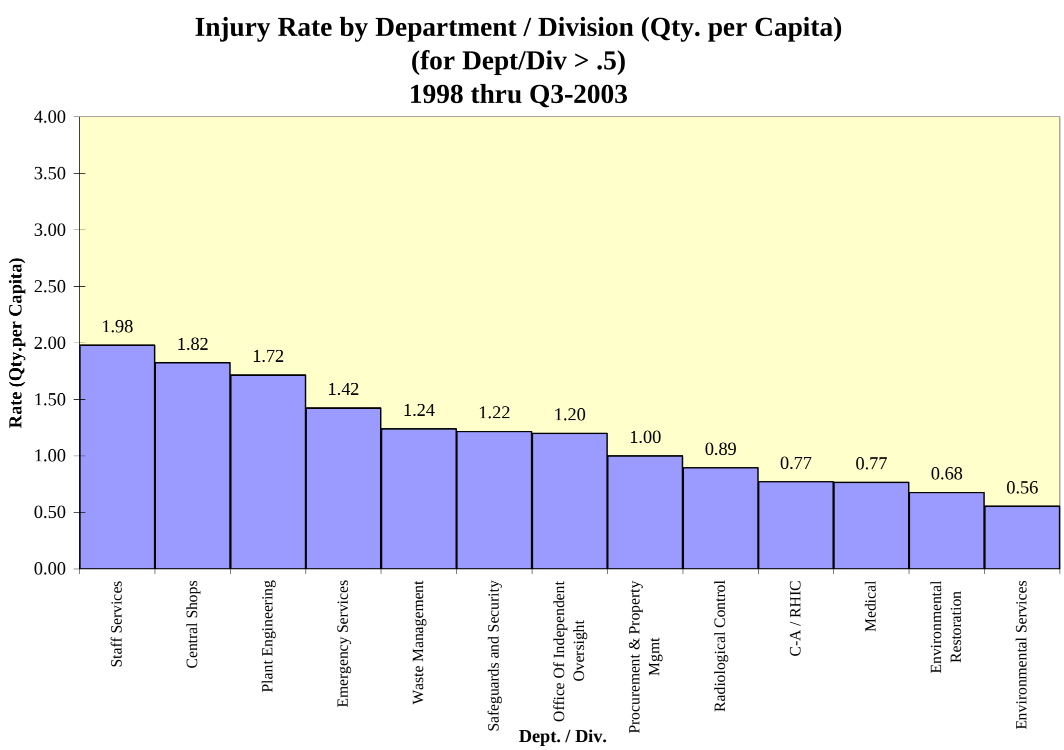


Figure 16. Injury Rate by Department/Division

The Task Force also evaluated injury data by Department/Division. These data could be normalized because work hours are categorized by Department/Division. Figure 16 shows the injury rates by Department/Division for those Departments/Divisions having an injury rate greater than 0.5. Initially, the High Energy and Nuclear Physics Directorate and the Director's Office were among the highest injury rates. Further investigation revealed over 38 Guest/ Collaborator injuries, 36 of which occurred in C-AD, were assigned to the High Energy and Nuclear Physics Directorate, and the Red Cross injuries were assigned to the Director's office. Reassigning these injuries produced the results presented in Figure 16. It is also interesting to note that the Office of Independent Oversight and the Medical Department, relatively small and low risk groups, have greater injury rates than the Environmental Restoration and Environmental Services Divisions.

D. Computerized Accident/Incident Reporting System (CAIRS)

The Computerized Accident/Incident Reporting System (CAIRS) is the Department of Energy's complex-wide database for collecting and analyzing injuries, illnesses and other accidents that occur during DOE operations. Input is required by DOE Order 231.1 for DOE contractors and subcontractors. CAIRS reporting thresholds for injuries and illnesses are consistent with OSHA guidelines for recordable events. The database does not include information on near misses, first aid cases and injuries that resulted in no significant lost time. In addition to injuries and illnesses, CAIRS collects data on property damage and vehicle accident events.

Office of Science (SC) laboratories have been reducing injury rates steadily since 1998. Ray Orbach (SC-1) has proposed injury rate goals for 2007 that reflect performance on par with "best-in-class" for the industry. Brookhaven National Laboratory's injury rates have been higher than the SC average for the last few years, as demonstrated in Figure 17 through Figure 20, and Table 14. BNL's Total Recordable Case Rate and Lost Workday Case Rate demonstrated sharp declines from 1998 to 2000, after which they both began to rise. The rates for the first three quarters of 2003 showed a decline, although the graphs only reflect injuries through June 2003. The Lost Workday Case Rate increases to 0.88 for injury data through the end of FY 2003.

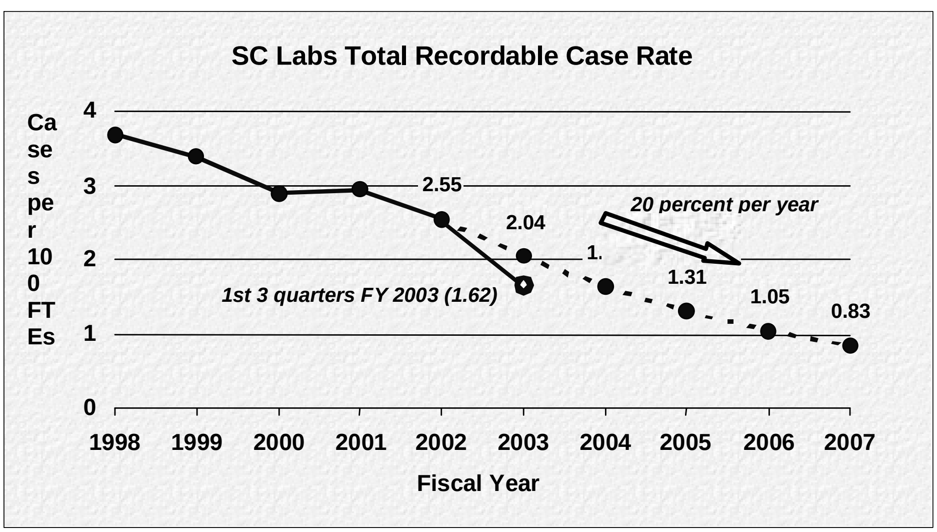


Figure 17: Total Recordable Case Rate for all Office of Science laboratories since 1998. Also depicted in the chart is the projected decline needed to reach a goal of 0.83 (considered industry "best in class") by the year 2007.

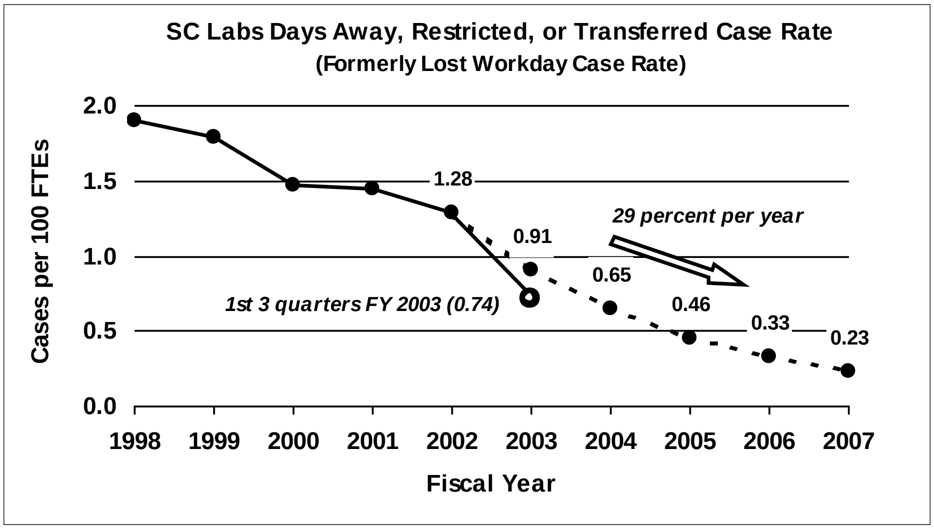


Figure 18: Lost Workday Case Rate for all Office of Science laboratories since 1998. Also depicted in the chart is the projected decline needed to reach a goal of 0.23 (considered "best in class") by the year 2007.

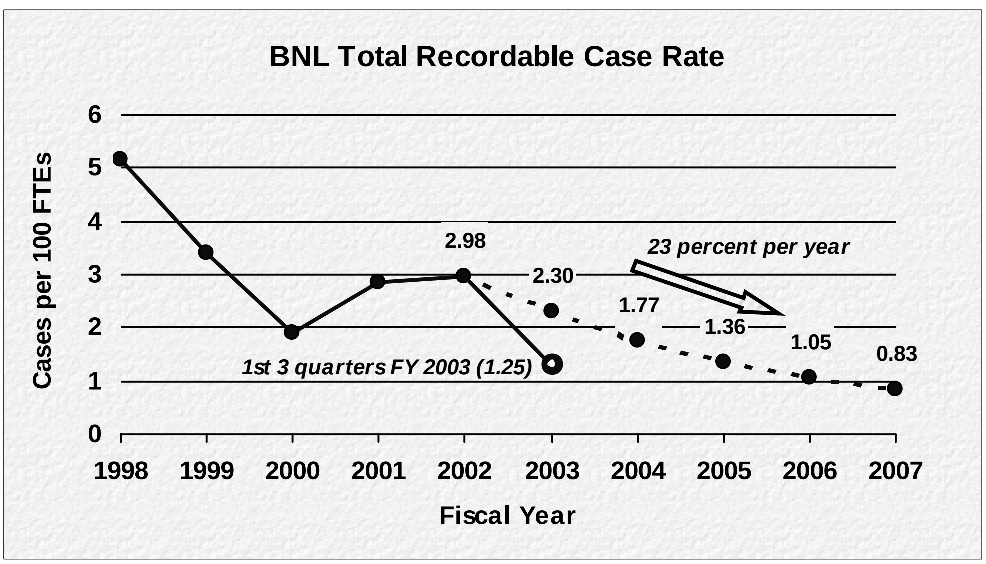


Figure 19: Total Recordable Case Rate for BNL since 1998 and the projected decline needed to reach the "best in class" goal by the year 2007.

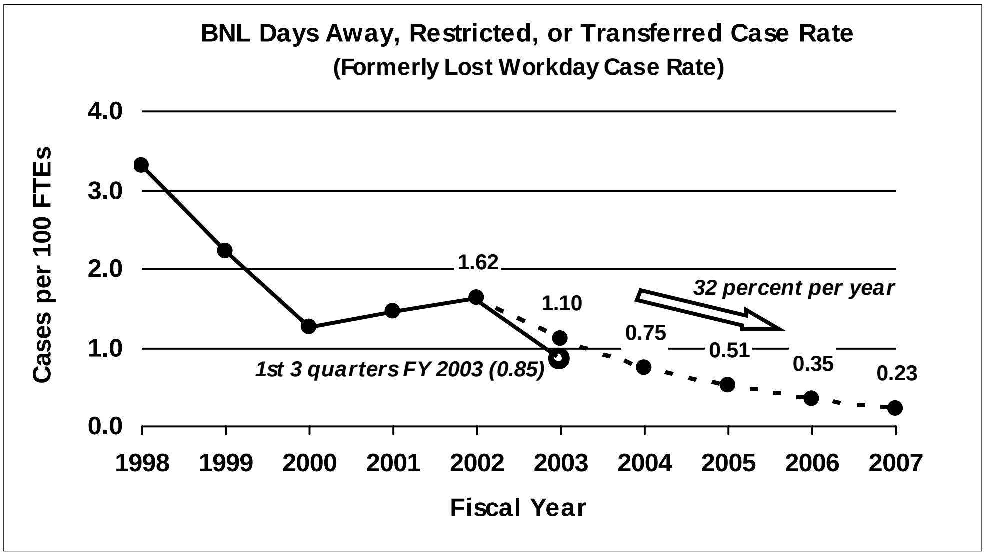


Figure 20: Lost Workday Case Rate for BNL since 1998 and the projected decline needed to reach the "best in class" goal of 0.23 by the year 2007.

Table 14 also shows that in 2002, BNL had the 2nd worst LWCR among the 10 Office of Science laboratories. In 2003, BNL's LWCR shows a significant reduction, nearly 50%, but ranks 4th worst among the laboratories. According to the February 2003 BNL report titled "*Analysis of Occupational Injuries at BNL*," BNL also ranked 4th worst for Lost Workday Case Rate in 2002 among 26 DOE facilities.

Table 14. Comparing Lost Workday Case Rate (LWCR) for 2002 and 2003 (1st 3 Quarters) across the Office of Science (SC)

	2002		2003	
Organization	**LWCR**	**Rank**	**LWCR**	**Rank**
All SC Labs	*1.28*	-	*0.74*	-
Ames Laboratory	0.33	10	0.42	10
Argonne National Laboratory-East	1.41	5	0.85	4
Brookhaven National Laboratory	**1.62**	**2**	**0.85**	**4**
Fermi National Accelerator Laboratory	1.46	4	0.30	9
Lawrence Berkeley National Laboratory	1.11	6	0.81	6
Oak Ridge National Laboratory	1.48	3	0.52	8
Pacific Northwest National Laboratory	0.93	9	0.96	3
Princeton Plasma Physics Laboratory	1.75	1	1.17	1
Stanford Linear Accelerator Center	0.98	8	0.74	7
Thomas Jefferson National Accelerator Facility	1.02	7	1.02	2

E. Radiological Awareness Reports (RAR)

Radiological Awareness Reports (RARs) are used for notifying Laboratory management of radiological deficiencies and incidents, and for addressing concerns relating to radiological hazards. The purpose of the RARs is to make management aware of issues that have an effect on the radiological control program, to provide a system for managing identified issues, and to standardize the criteria and methodology for investigating radiological events.

Examples of RARs include:

- Failure to comply with radiological postings or Radiological Work Permit (RWP) requirements;
- Unauthorized modifications of radiological postings, barriers, or dosimetry;
- Unauthorized release of materials from controlled areas;
- Poor radiological work practices; and
- Leak from a radiological process.

This procedure is applicable to all Laboratory personnel who may identify radiological concerns. In particular, to those personnel who perform, support, manage, or control equipment, materials, services, procedures, measurement, or other activities associated with the implementation of the radiation protection program at BNL.[2] The RAR system did not exist before 1999, therefore the Task Force could not adhere to the self-imposed review period of 1998 through third calendar quarter 2003.

The Task Force evaluated RAR data as another part of the BNL Safety Management System and another source for trending information. This information became the most revealing source for the Task Force's conclusions regarding the underlying cause for the safety problems at BNL. The first data to be reviewed are shown in Figure 21. This Figure shows that the Radiological Control Division, the Division whose mission is the "Protection of workers and public from the hazards of radiation, and protection of the Laboratory from radiological issues," has the third highest number of reports. is the highest number of reports in the RAR system is the Medical Department, a relatively small department at the Laboratory. The Task Force normalized the data to rate, which is shown in Figure 22. This Figure shows the Medical Department still ranks as third highest number of reports. Finally, the Task Force evaluated the types of incidents that were recorded. This is shown in Figure 23. Forty percent (40%) of the RAR infractions, Procedure Violation and Posting, are failures by workers to adhere to procedures and signs. This observation bolsters the conclusions drawn in Section II.E that workers are disregarding procedures and safety.

[2] Background taken from https://sbms.bnl.gov/standard/0v/0v00i011.htm

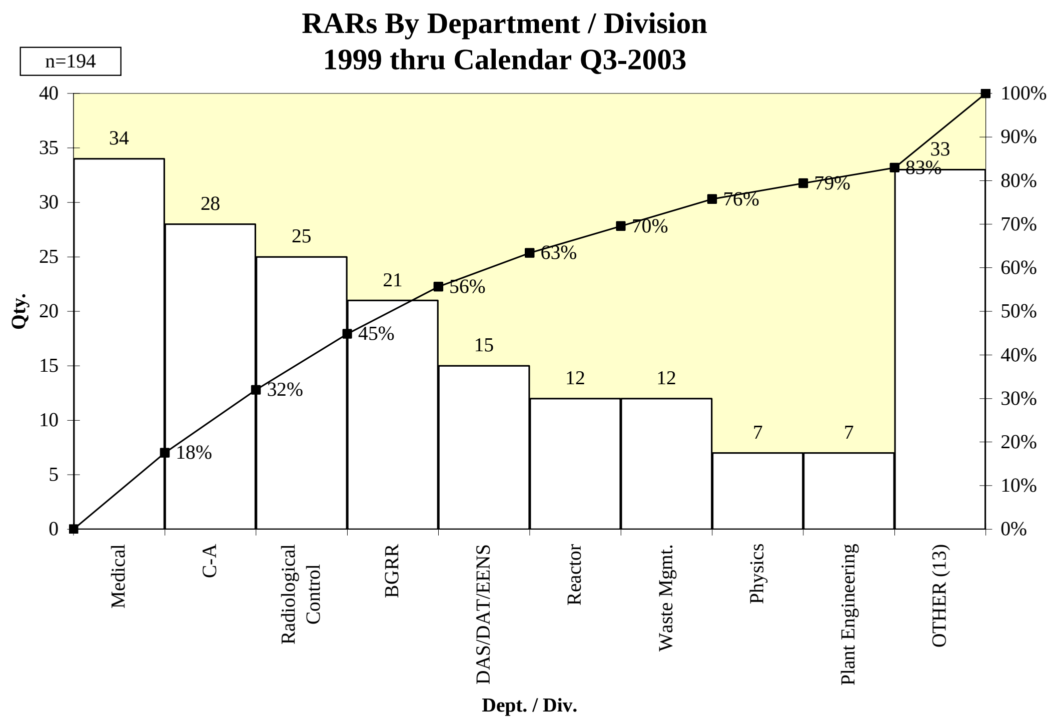


Figure 21. RARs by Department/Division 1999 – Q3 2003

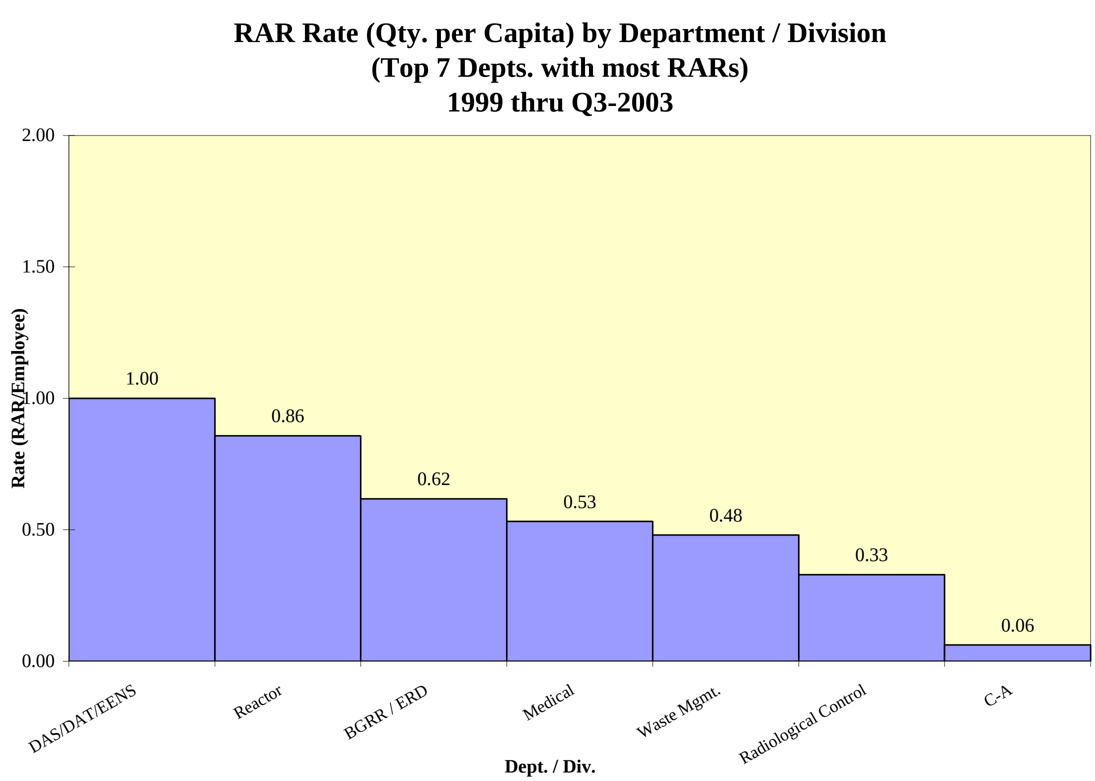


Figure 22. RAR Rate by Department/Division, Top 7

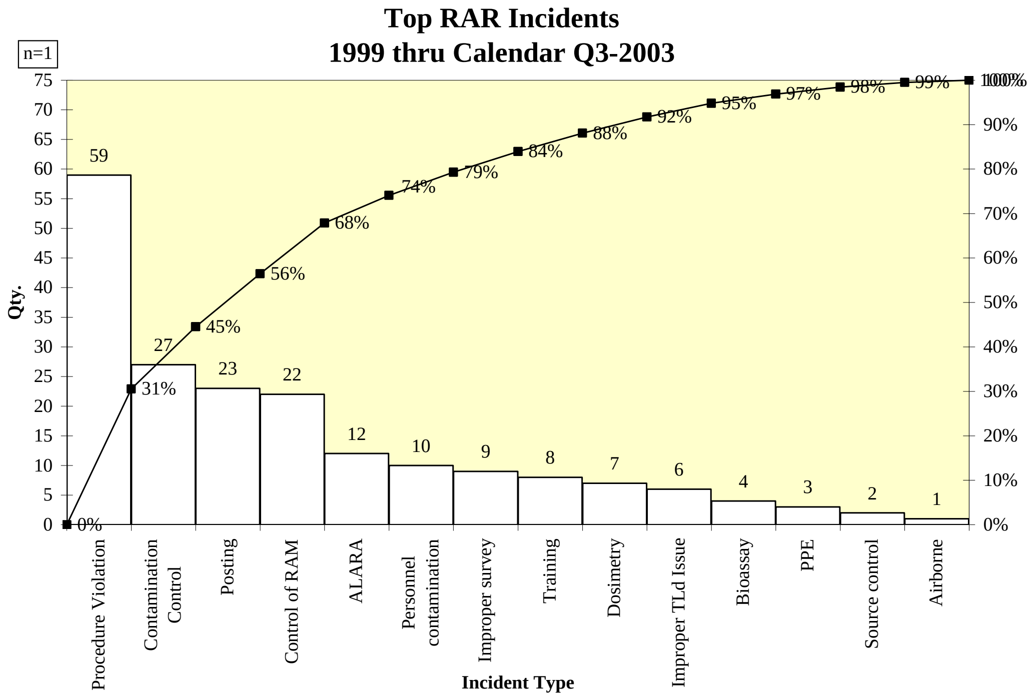


Figure 23. RAR Incidents by Type

F. Human Resources Data

Human Resources data were evaluated to determine whether the increases in incidents in 2003 are attributed to workers under stress, and whether the third calendar quarter is a time when workers are vacationing, putting schedule stress on the workers that were not vacationing. Figure 24 shows the number of layoffs at BNL over the time period evaluated. The Figure does, indeed, show that layoff increased in 2003, and that the number of involuntary layoffs greatly exceeded the number of voluntary layoffs for the first time in the review period. This would indicate that there may be worker stress. This is just an observation of the Task Force, but warrants further investigation.

Figure 25 shows the number of hours worked during the review period, plotted by calendar quarter. This Figure also helps to refute the hypothesis that workers are vacationing during the third quarter, putting additional schedule stress on their co-workers that remained. In fact, the Figure shows that, with the exception of 2001 and 2002, the third calendar quarter has the greatest number of hours worked.

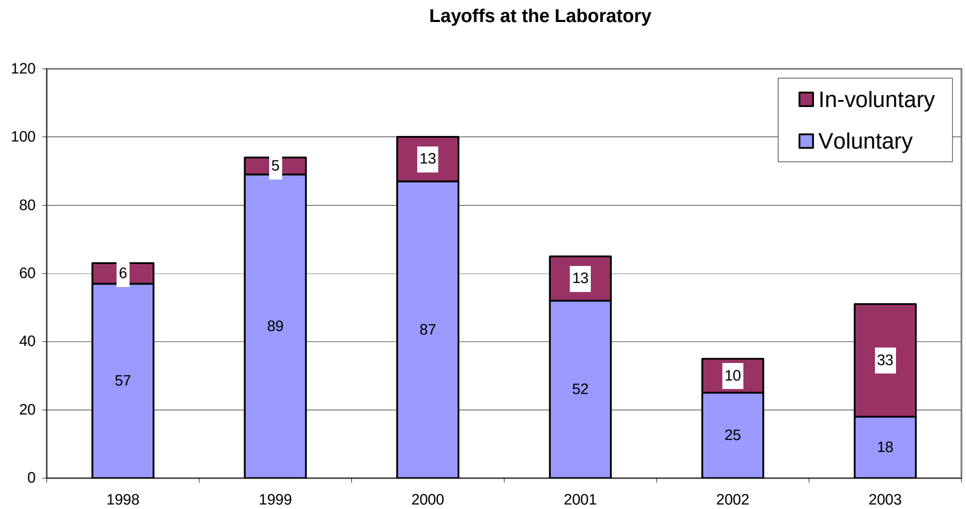


Figure 24. Layoffs at the Laboratory

As discussed briefly in Section III.C, the Task Force found that there were over 700 job titles during the six-year period reviewed. Several "acting" positions were identified, mostly for senior management. This was not considered healthy for the organization. Acting positions can be viewed by workers as indicating a lack of concern by management for the direction and leadership of the organization. For a variety of reasons, persons in 'acting' positions may not feel empowered to demonstrate leadership and enact changes that may be necessary to improve worker safety. Overall, it may be perceived as a weakening of the coherence of the operational infrastructure, and a failure to provide strong "top-down" support for safety, etc. programs. This potential impact to the organizational culture requires significantly more investigation before a conclusion can be drawn, but the Task Force believes that this effort should be undertaken.

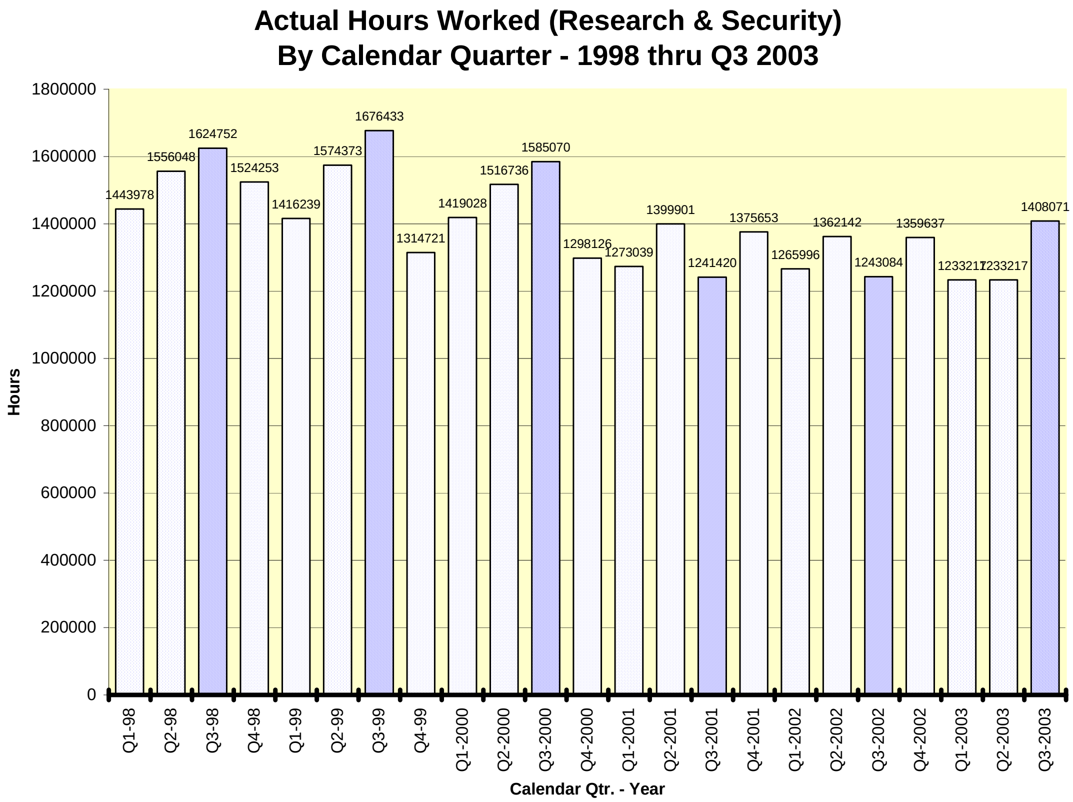


Figure 25. Actual Hours Worked, by Quarter

IV. Conclusions, Observations and Recommendations

A. Conclusions

1. It is concluded that there is a breakdown in BNL's Safety Management System because the safety information management systems are ineffective. It became readily apparent at the very beginning of this effort that BNL does not have a safety management information system. There are several data systems available, but these are not configured to provide the information necessary to discover and evaluate trends. Much of the Task Force's effort was spent capturing data and developing it into useful information.
2. It became apparent early on that the depth and breadth of the ORPS Occurrence investigations varied widely, and were susceptible to some subjectivity. This makes it difficult to trend data because the data itself is not correct or at least held to some standard of quality. This was observed during the analysis of the ten ORPS Occurrences that triggered this investigation.
3. The single most significant common cause for ORPS and RAR Occurrences was found to be a failure of Work Process Controls. This means work is not being planned or thought out by the people involved in the occurrence, either directly or indirectly; hazards are not being considered or addressed; and training, procedures, or Laboratory Standards are being ignored.
4. The second most significant common cause for ORPS Occurrences is workers and/or management are not doing their job adequately or are not taking the time necessary to understand the task at hand.
5. The 7 Deadly Sins Analysis found people are ignoring standards, procedures and/or good and accepted safe practice, or they are assuming someone else is taking care of safety and aren't bothering to find out if that is true.
6. The analysis of the ten ORPS Occurrences demonstrates that workers, supervisors and managers involved, either directly or indirectly, in these occurrences do not place enough emphasis on planning, and doing work safely and following procedures/standards. This was not isolated to just one group or department.
7. The overall trends for ORPS Occurrences and injuries (OSMIS) (rate and total count) at BNL are continuing downward for the period reviewed. However, ORPS Occurrences are increasing consistently since their low during Q4-2002.
8. Some relatively small Departments/Divisions, specifically the Medical and Chemistry Departments, experience high numbers of ORPS Occurrences. When the data were normalized to rates, The Medical and Chemistry Departments have the highest rates for Scientific Departments.
9. It appears from the ORPS data that the rise in incidents is not from worker fatigue due to excess hours worked. The great majority of incidents are reported during the period 1400–1600 (2–4 p.m.), and the majority of the incidents are discovered during daytime working hours. The Occurrences do not appear to be occurring overnight because there was no spike in discovery time during the period 0800 – 1000, when the workday starts and overnight incidents would most likely be

discovered. However, the information systems did not contain the time of occurrence. The information captured is time of discovery.

10. The number of injuries and ORPS Occurrences in the third quarter is not statistically significantly higher than the other quarters. The data available do not indicate that time pressures or changes in work hours in the third quarter lead to more occurrences.
11. Technicians were not over-represented in the OSMIS (injury) data. Once the trades were consolidated, their combined injury rates were more inline with their scientific department equivalents, Technicians. The third and fifth highest number of injuries at BNL are white collar jobs. These are Administrative and Engineer. Combined, they account for 16% of the injuries at BNL.
12. The CAIRS data show that BNL had the second highest Lost Workday Case Rate (LWCR) among the ten Office of Science laboratories in 2002. BNL's LWCR shows a significant reduction in 2003, nearly 50%, but BNL still ranks fourth highest among the laboratories.
13. The highest number of reports in the RAR system is the Medical Department, a relatively small department at the Laboratory. The Radiological Awareness Report (RAR) data show that the Radiological Control Division, the Division whose mission is the "Protection of workers and public from the hazards of radiation, and protection of the Laboratory from radiological issues," is the third highest number of reports.
14. Forty percent (40%) of the RAR infractions, Procedure Violation and Posting, are failures by workers to adhere to procedures and signs. This fact bolsters the conclusion that workers are disregarding procedures and safety.

B. Observations

1. The Departments/Divisions performing environmental clean-up work have the highest ORPS Occurrence rates at BNL.
2. The third quarter is not always the quarter with the highest number or rate for ORPS Occurrences.
3. The OSMIS does not always include the work hours for Guest/Collaborator and Red Cross. Guest/Collaborator injuries are not consistently assigned to the organization within which they are working/injured. There were also 38 injuries in the OSMIS data for which there is no job classification. This would indicate that the data captured for this management system are not adequate, and another indication that the safety management systems at BNL are not working.
4. Guests and Collaborators are being injured while here at the Laboratory at a rate greater than their Scientific employee counterparts. This may mean our Guests and Collaborators are not being trained and/or supervised properly while here at BNL. The same observation is made for the category Student Assistant.
5. The Red Cross has a facility here at BNL, a kitchen, hosted by the Medical Department. They average four injuries per year. These people are not BNL

employees. And while they operate a kitchen, they have had twice as many injuries for the timeframe studied as professional Food Preparers also working here at BNL.

6. Overexertion injuries were in the top two injury types for the workers that were evaluated. The Task Force believes overexertion injuries are attributable to ergonomic issues, and warrants further investigation.
7. Office of Independent Oversight and the Medical Department, relatively small and low risk groups, have greater injury rates than the Environmental Restoration and Environmental Services Divisions.

C. Recommendations

1. A number of cultural issues were identified (conclusions 4-7) during this investigation. A holistic approach is suggested to address the cultural factors that impede safety performance in order to achieve a sustainable solution.
2. The safety data systems and Human Resources databases should be evaluated and upgraded to ensure all appropriate information is captured (Job titles, Guest work-hours, etc.) and provide useful trending and safety information.
3. Overexertion injuries may be indicative of ergonomic issues or an aging workforce at BNL, and warrants further investigation.
4. Layoff data would indicate that there may be worker stress, and warrants further investigation.
5. The Task Force recommends an evaluation of the impact "acting" positions are having on the culture here at BNL. "Acting" positions may be perceived as a weakening of the coherence of the operational infrastructure, and a failure to provide strong "top-down" support for safety, etc. programs.
6. The unreportable ORPS Occurrences should be reviewed for underlying trends and to determine whether the classification as unreportable is uniformly applied.
7. Establish a mechanism to assure consistent and objective causal analysis.
8. Managers at BNL need to fully understand the scope of work required before making a skill-of-the-craft determination, and encourage workers to report back when conditions are non-routine or outside the expected realm of experience and expertise. Managers should also more closely examine activities among their skill-of-the-craft employees to determine if risky work practices are exposing workers to hazardous conditions. This is particularly of concern when unexpected field conditions are encountered.
9. Workers should understand the limits of their expertise and not hesitate to seek additional guidance.

D. Lessons Learned

1. Take personal responsibility for your own safety and those around you in all aspects of performing your job.
2. Follow established procedures for safe work practices and do not exceed rated working envelopes for equipment. Specifically, do no assume there are factors of safety beyond the rated working envelope.
3. When performing work planning and work permits consider second order impacts of the activities to be performed if these activities are not typical of day-to-day activities.
4. As a supervisor, group leader, principal investigator or other that is responsible for guests or visitors, verify they are properly trained and try to instill in them a culture of personal responsibility for safety.
5. Stress the importance of thorough work planning and stopping to reevaluate controls in the fields when conditions change or are not found to be as expected.

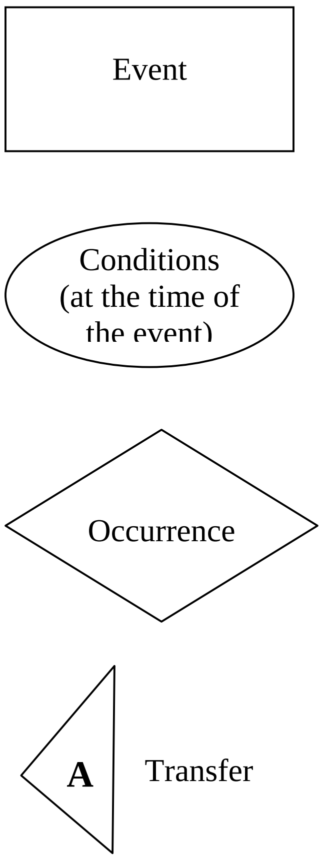
APPENDIX A

EVENTS AND CAUSAL FACTOR CHARTS

FOR

ORPS OCCURRENCES

LEGEND:


Event
Conditions
(at the time of
the event)
Occurrence
A
Transfer

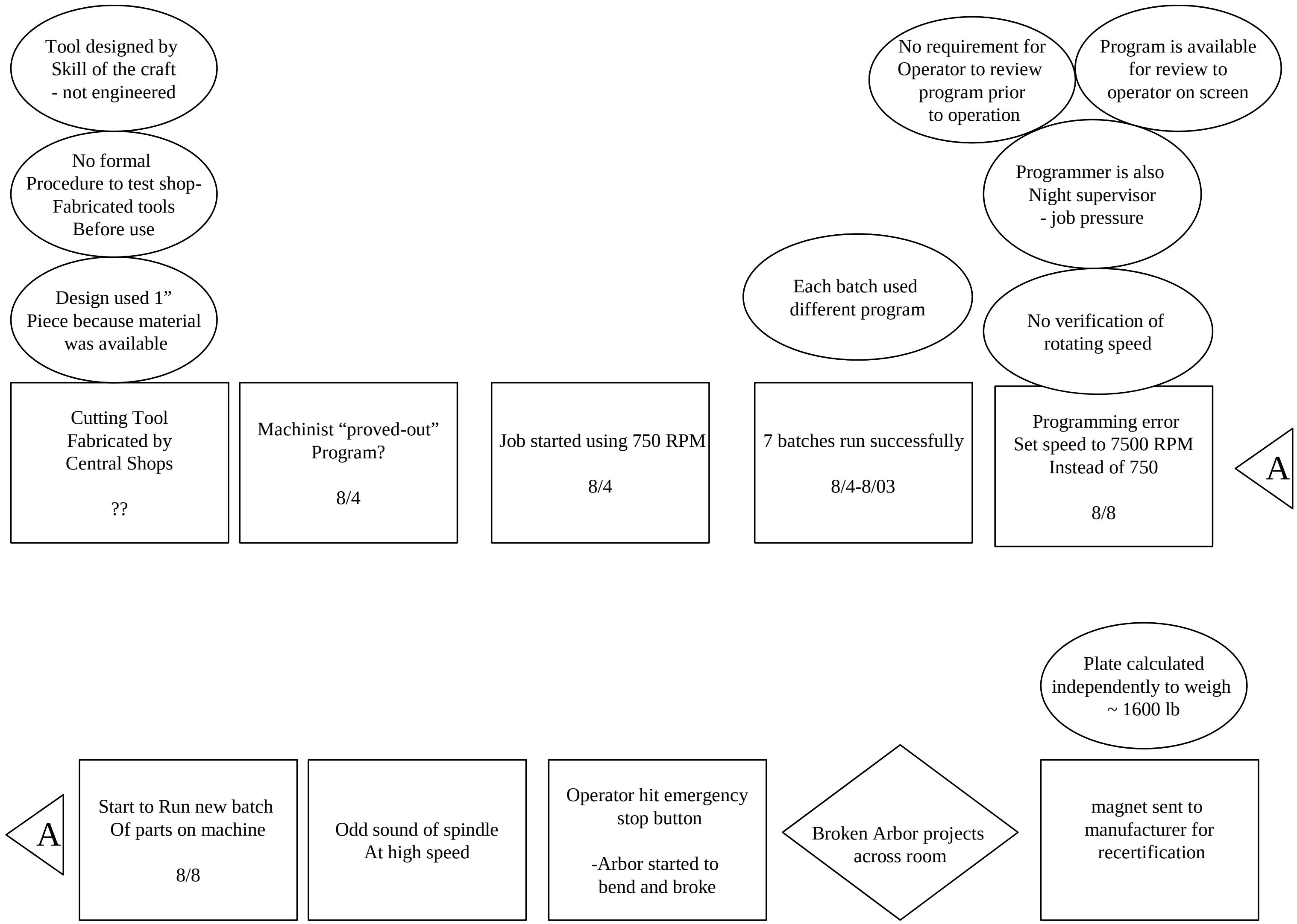

Tool designed by Skill of the craft - not engineered
No formal Procedure to test shop- Fabricated tools Before use
Design used 1” Piece because material was available
Cutting Tool Fabricated by Central Shops ??
Machinist “proved-out” Program? 8/4
Job started using 750 RPM 8/4
Each batch used different program
7 batches run successfully 8/4-8/03
No requirement for Operator to review program prior to operation
Program is available for review to operator on screen
Programmer is also Night supervisor - job pressure
No verification of rotating speed
Programming error Set speed to 7500 RPM Instead of 750 8/8
A
A
Start to Run new batch Of parts on machine 8/8
Odd sound of spindle At high speed
Operator hit emergency stop button -Arbor started to bend and broke
Broken Arbor projects across room
Plate calculated independently to weigh ~ 1600 lb
magnet sent to manufacturer for recertification

Figure A-1.

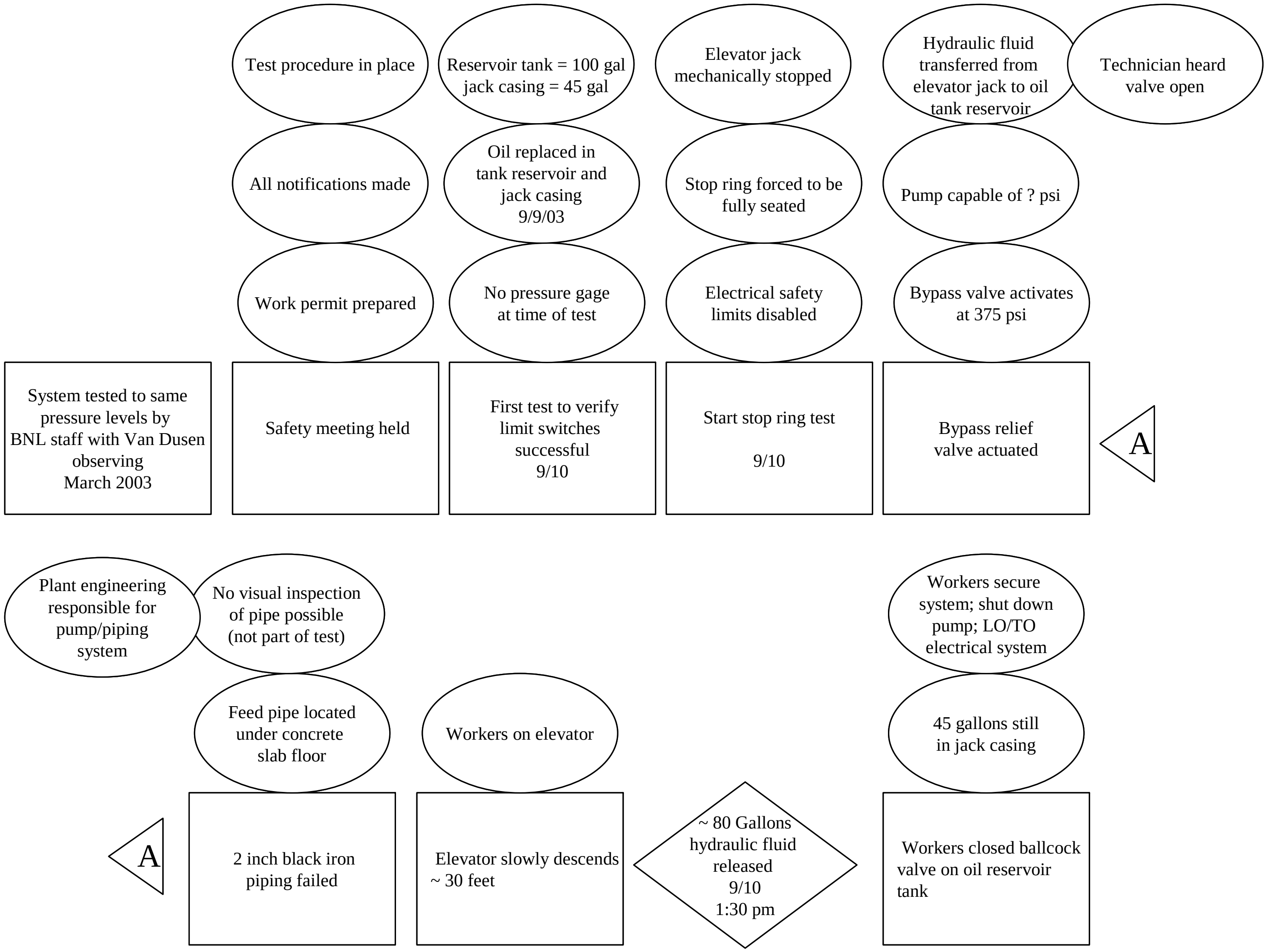

Test procedure in place
Reservoir tank = 100 gal jack casing = 45 gal
Elevator jack mechanically stopped
Hydraulic fluid transferred from elevator jack to oil tank reservoir
Technician heard valve open
All notifications made
Oil replaced in tank reservoir and jack casing 9/9/03
Stop ring forced to be fully seated
Pump capable of ? psi
Work permit prepared
No pressure gage at time of test
Electrical safety limits disabled
Bypass valve activates at 375 psi
System tested to same pressure levels by BNL staff with Van Dusen observing March 2003
Safety meeting held
First test to verify limit switches successful 9/10
Start stop ring test 9/10
Bypass relief valve actuated
A
Plant engineering responsible for pump/piping system
No visual inspection of pipe possible (not part of test)
Workers secure system; shut down pump; LO/TO electrical system
Feed pipe located under concrete slab floor
Workers on elevator
45 gallons still in jack casing
A
2 inch black iron piping failed
Elevator slowly descends ~ 30 feet
~ 80 Gallons hydraulic fluid released 9/10 1:30 pm
Workers closed ballcock valve on oil reservoir tank

Figure A-2.

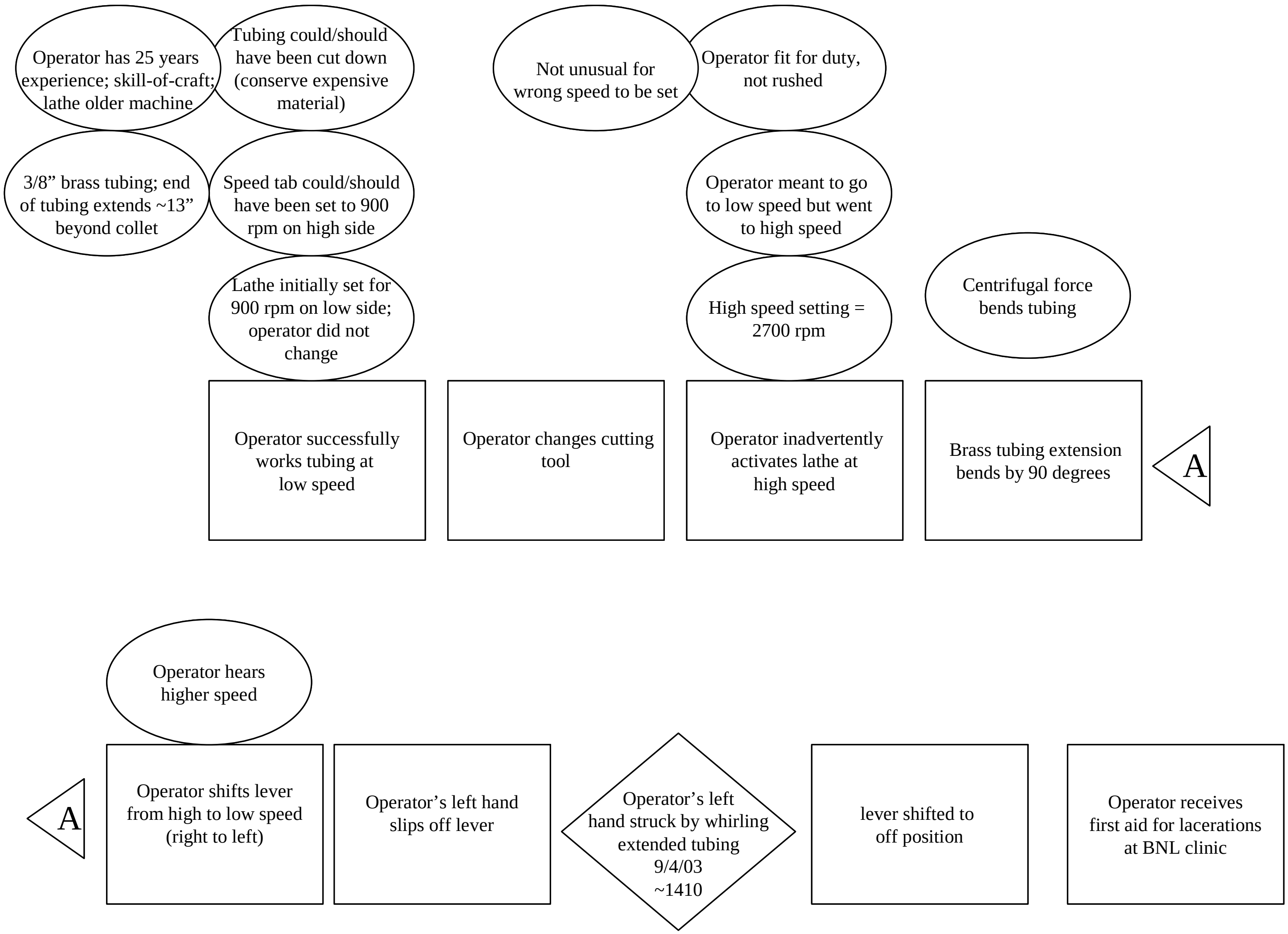

Operator has 25 years experience; skill-of-craft; lathe older machine
Tubing could/should have been cut down (conserve expensive material)
Not unusual for wrong speed to be set
Operator fit for duty, not rushed
3/8” brass tubing; end of tubing extends ~13” beyond collet
Speed tab could/should have been set to 900 rpm on high side
Operator meant to go to low speed but went to high speed
Lathe initially set for 900 rpm on low side; operator did not change
High speed setting = 2700 rpm
Centrifugal force bends tubing
Operator successfully works tubing at low speed
Operator changes cutting tool
Operator inadvertently activates lathe at high speed
Brass tubing extension bends by 90 degrees
A
Operator hears higher speed
A
Operator shifts lever from high to low speed (right to left)
Operator’s left hand slips off lever
Operator’s left hand struck by whirling extended tubing 9/4/03 ~1410
lever shifted to off position
Operator receives first aid for lacerations at BNL clinic

Figure A-3.

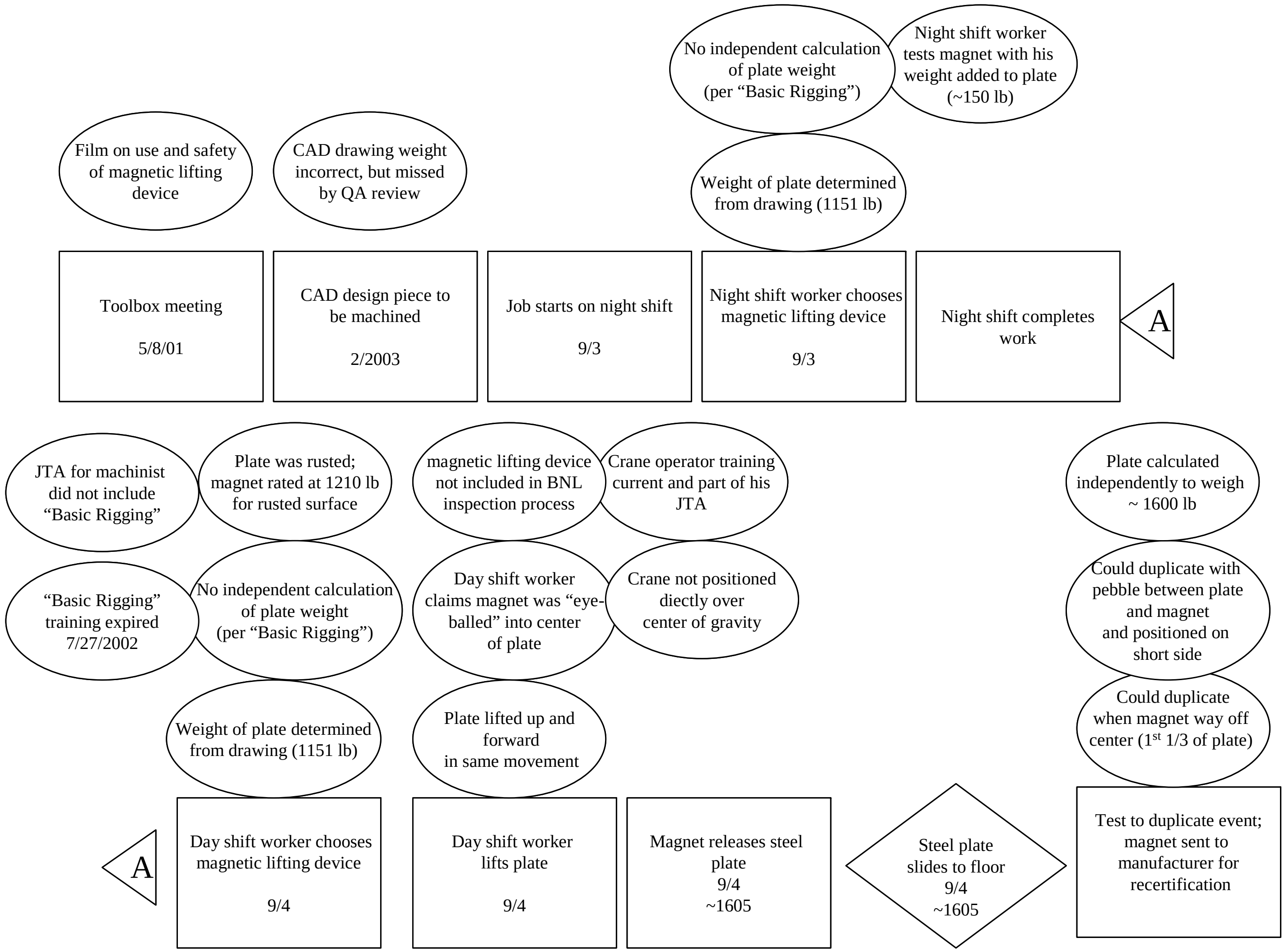

No independent calculation of plate weight (per "Basic Rigging")
Night shift worker tests magnet with his weight added to plate (~150 lb)
Film on use and safety of magnetic lifting device
CAD drawing weight incorrect, but missed by QA review
Weight of plate determined from drawing (1151 lb)
Toolbox meeting
5/8/01
CAD design piece to be machined
2/2003
Job starts on night shift
9/3
Night shift worker chooses magnetic lifting device
9/3
Night shift completes work
A
JTA for machinist did not include "Basic Rigging"
Plate was rusted; magnet rated at 1210 lb for rusted surface
magnetic lifting device not included in BNL inspection process
Crane operator training current and part of his JTA
Plate calculated independently to weigh ~ 1600 lb
"Basic Rigging" training expired 7/27/2002
No independent calculation of plate weight (per "Basic Rigging")
Day shift worker claims magnet was "eye-balled" into center of plate
Crane not positioned diectly over center of gravity
Could duplicate with pebble between plate and magnet and positioned on short side
Weight of plate determined from drawing (1151 lb)
Plate lifted up and forward in same movement
Could duplicate when magnet way off center (1st 1/3 of plate)
A
Day shift worker chooses magnetic lifting device
9/4
Day shift worker lifts plate
9/4
Magnet releases steel plate
9/4
~1605
Steel plate slides to floor
9/4
~1605
Test to duplicate event; magnet sent to manufacturer for recertification

Figure A-4

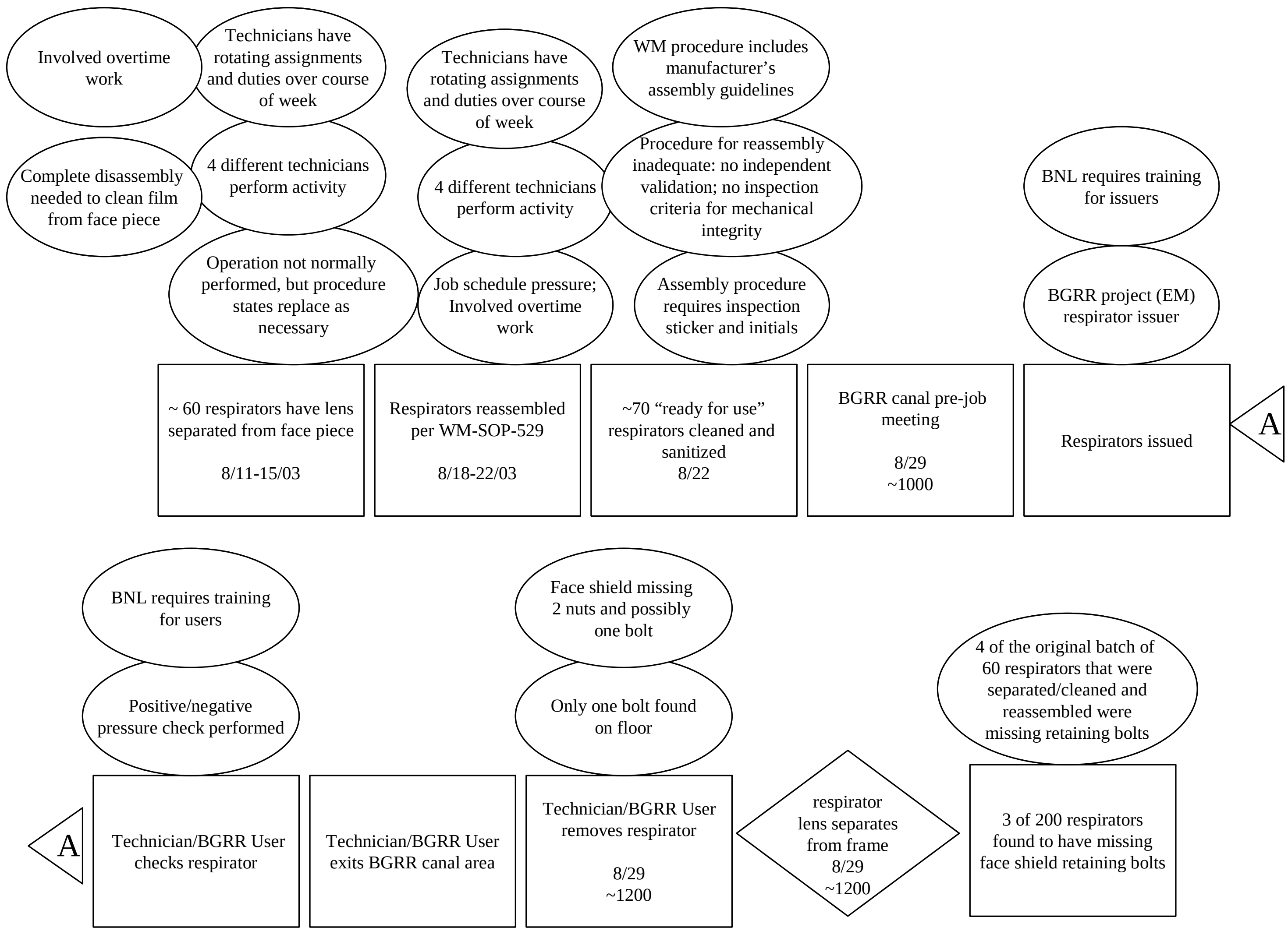

Involved overtime work
Technicians have rotating assignments and duties over course of week
Complete disassembly needed to clean film from face piece
4 different technicians perform activity
Operation not normally performed, but procedure states replace as necessary
Technicians have rotating assignments and duties over course of week
4 different technicians perform activity
Job schedule pressure; Involved overtime work
WM procedure includes manufacturer's assembly guidelines
Procedure for reassembly inadequate: no independent validation; no inspection criteria for mechanical integrity
Assembly procedure requires inspection sticker and initials
BNL requires training for issuers
BGRR project (EM) respirator issuer
~ 60 respirators have lens separated from face piece
8/11-15/03
Respirators reassembled per WM-SOP-529
8/18-22/03
~70 "ready for use" respirators cleaned and sanitized
8/22
BGRR canal pre-job meeting
8/29
~1000
Respirators issued
A
BNL requires training for users
Positive/negative pressure check performed
Face shield missing 2 nuts and possibly one bolt
Only one bolt found on floor
4 of the original batch of 60 respirators that were separated/cleaned and reassembled were missing retaining bolts
A
Technician/BGRR User checks respirator
Technician/BGRR User exits BGRR canal area
Technician/BGRR User removes respirator
8/29
~1200
respirator lens separates from frame
8/29
~1200
3 of 200 respirators found to have missing face shield retaining bolts

Figure A-5

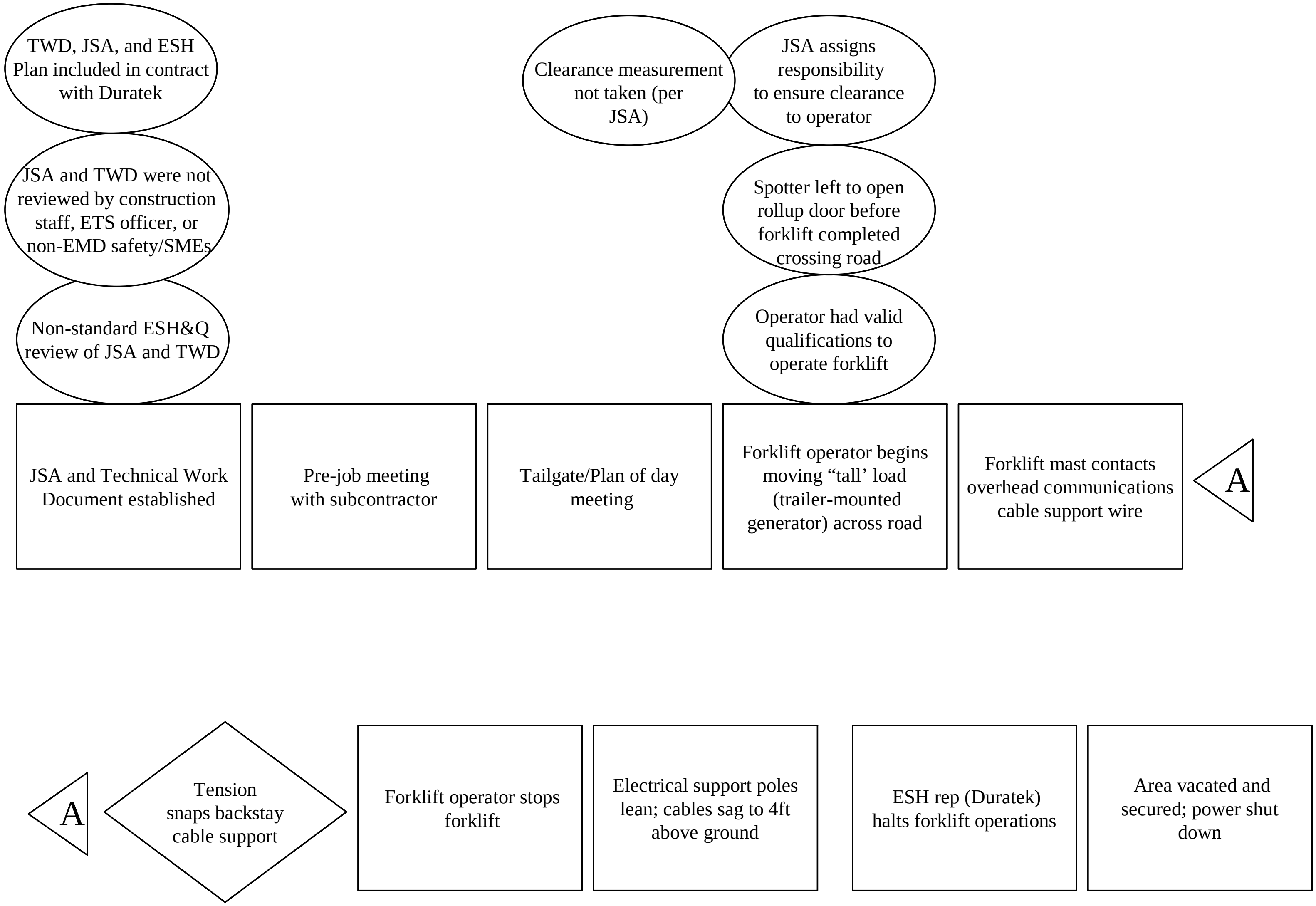

TWD, JSA, and ESH Plan included in contract with Duratek
JSA and TWD were not reviewed by construction staff, ETS officer, or non-EMD safety/SMEs
Non-standard ESH&Q review of JSA and TWD
Clearance measurement not taken (per JSA)
JSA assigns responsibility to ensure clearance to operator
Spotter left to open rollup door before forklift completed crossing road
Operator had valid qualifications to operate forklift
JSA and Technical Work Document established
Pre-job meeting with subcontractor
Tailgate/Plan of day meeting
Forklift operator begins moving "tall" load (trailer-mounted generator) across road
Forklift mast contacts overhead communications cable support wire
A
A
Tension snaps backstay cable support
Forklift operator stops forklift
Electrical support poles lean; cables sag to 4ft above ground
ESH rep (Duratek) halts forklift operations
Area vacated and secured; power shut down

Figure A-6

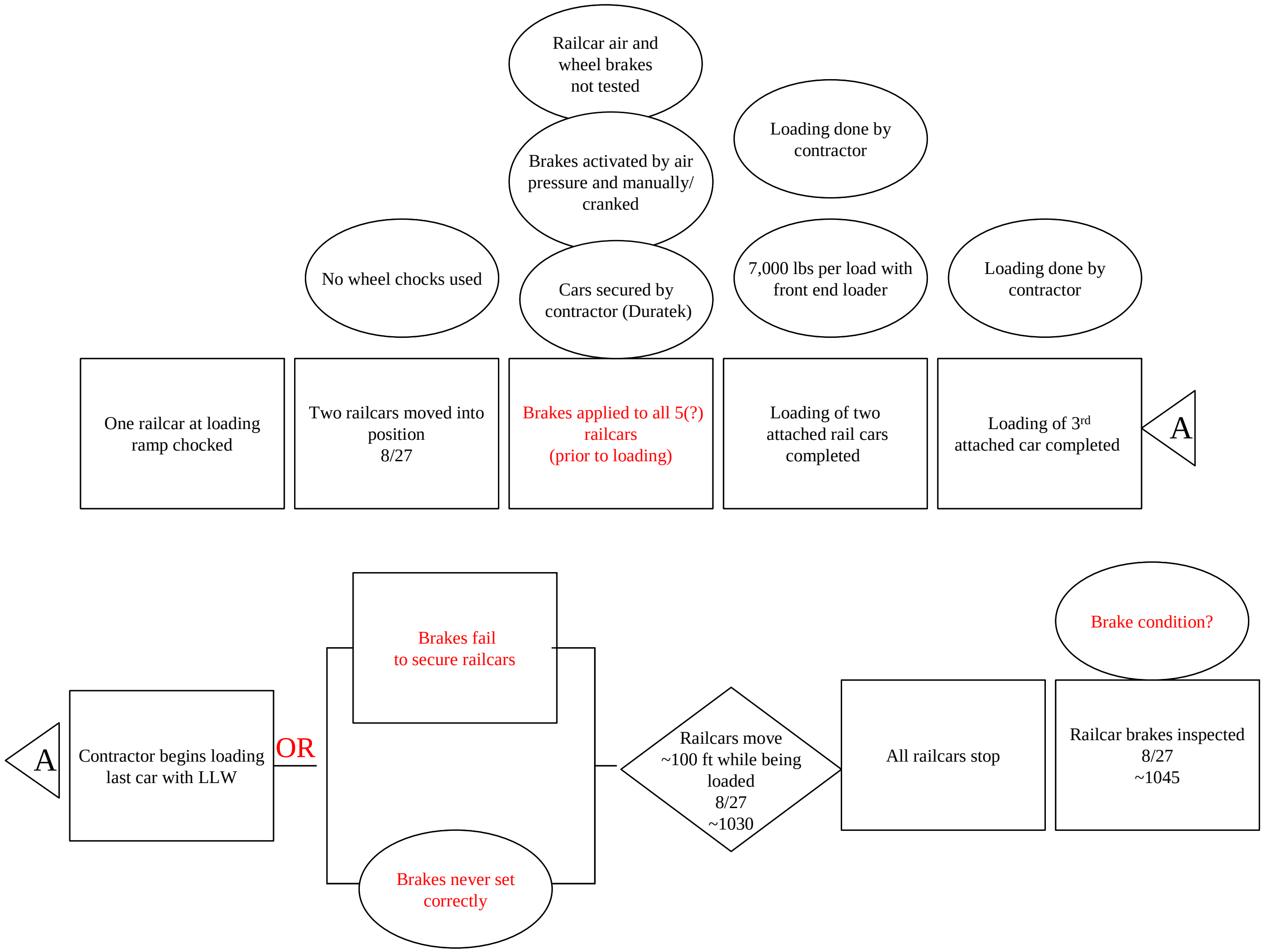

Railcar air and wheel brakes not tested
Brakes activated by air pressure and manually/ cranked
Loading done by contractor
No wheel chocks used
Cars secured by contractor (Duratek)
7,000 lbs per load with front end loader
Loading done by contractor
One railcar at loading ramp chocked
Two railcars moved into position 8/27
Brakes applied to all 5(?) railcars (prior to loading)
Loading of two attached rail cars completed
Loading of 3rd attached car completed
A
Brake condition?
Brakes fail to secure railcars
A
Contractor begins loading last car with LLW
OR
Railcars move ~100 ft while being loaded 8/27 ~1030
All railcars stop
Railcar brakes inspected 8/27 ~1045
Brakes never set correctly

Figure A-7

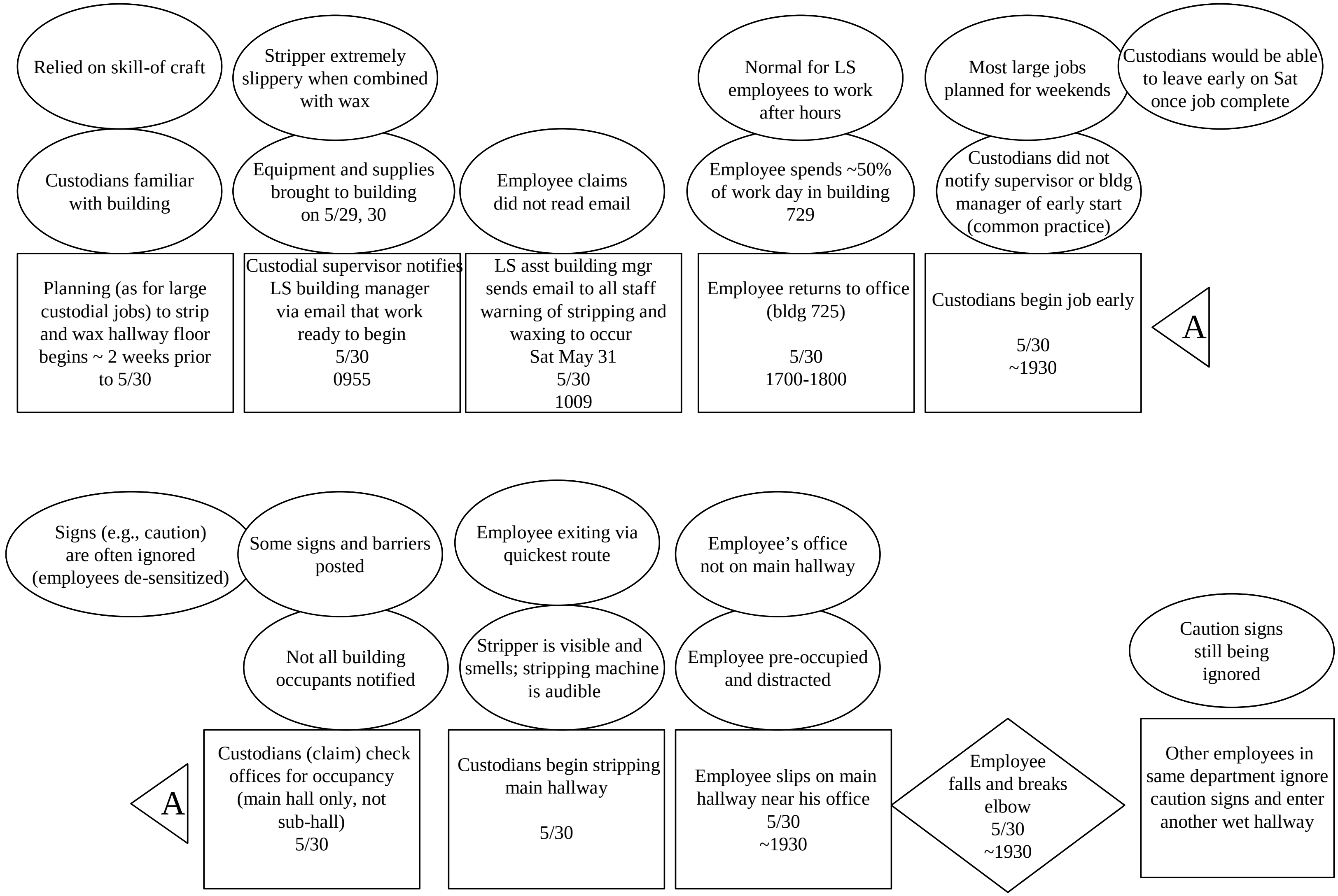

Relied on skill-of craft
Stripper extremely slippery when combined with wax
Normal for LS employees to work after hours
Most large jobs planned for weekends
Custodians would be able to leave early on Sat once job complete
Custodians familiar with building
Equipment and supplies brought to building on 5/29, 30
Employee claims did not read email
Employee spends ~50% of work day in building 729
Custodians did not notify supervisor or bldg manager of early start (common practice)
Planning (as for large custodial jobs) to strip and wax hallway floor begins ~ 2 weeks prior to 5/30
Custodial supervisor notifies LS building manager via email that work ready to begin 5/30 0955
LS asst building mgr sends email to all staff warning of stripping and waxing to occur Sat May 31 5/30 1009
Employee returns to office (bldg 725) 5/30 1700-1800
Custodians begin job early 5/30 ~1930
A
Signs (e.g., caution) are often ignored (employees de-sensitized)
Some signs and barriers posted
Employee exiting via quickest route
Employee's office not on main hallway
Not all building occupants notified
Stripper is visible and smells; stripping machine is audible
Employee pre-occupied and distracted
Caution signs still being ignored
A
Custodians (claim) check offices for occupancy (main hall only, not sub-hall) 5/30
Custodians begin stripping main hallway 5/30
Employee slips on main hallway near his office 5/30 ~1930
Employee falls and breaks elbow 5/30 ~1930
Other employees in same department ignore caution signs and enter another wet hallway

Figure A-8.

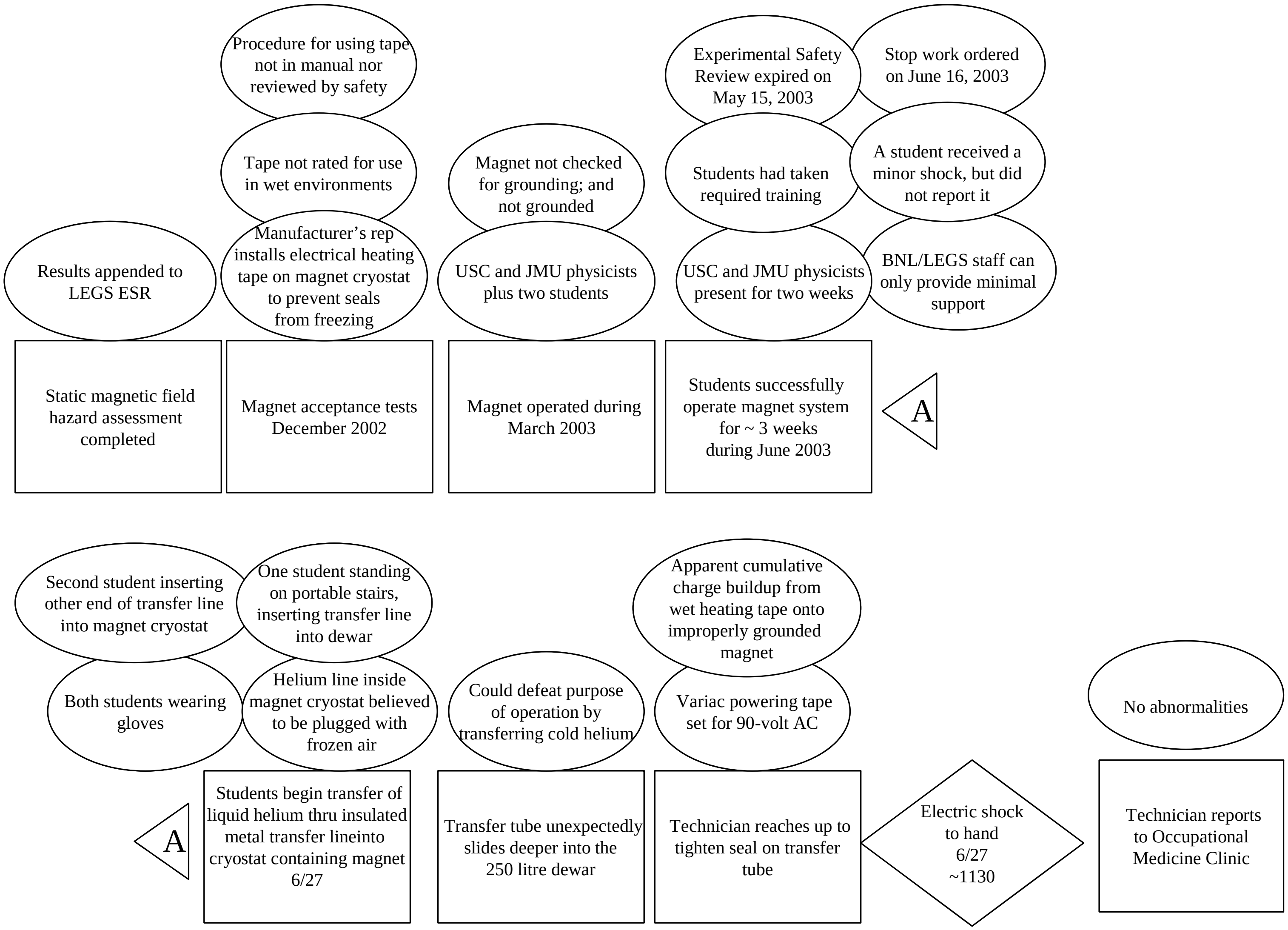

Procedure for using tape not in manual nor reviewed by safety
Tape not rated for use in wet environments
Manufacturer's rep installs electrical heating tape on magnet cryostat to prevent seals from freezing
Results appended to LEGS ESR
Magnet not checked for grounding; and not grounded
USC and JMU physicists plus two students
Experimental Safety Review expired on May 15, 2003
Stop work ordered on June 16, 2003
Students had taken required training
A student received a minor shock, but did not report it
USC and JMU physicists present for two weeks
BNL/LEGS staff can only provide minimal support
Static magnetic field hazard assessment completed
Magnet acceptance tests December 2002
Magnet operated during March 2003
Students successfully operate magnet system for ~ 3 weeks during June 2003
A
Second student inserting other end of transfer line into magnet cryostat
One student standing on portable stairs, inserting transfer line into dewar
Both students wearing gloves
Helium line inside magnet cryostat believed to be plugged with frozen air
Could defeat purpose of operation by transferring cold helium
Apparent cumulative charge buildup from wet heating tape onto improperly grounded magnet
Variac powering tape set for 90-volt AC
No abnormalities
A
Students begin transfer of liquid helium thru insulated metal transfer lineinto cryostat containing magnet 6/27
Transfer tube unexpectedly slides deeper into the 250 litre dewar
Technician reaches up to tighten seal on transfer tube
Electric shock to hand 6/27 ~1130
Technician reports to Occupational Medicine Clinic

Figure A-9

APPENDIX B

BATTELLE

CAUSAL CODES

Battelle Memorial Institute Causal Codes

Use of Causal Codes

Causal analysis will reveal potential conditions that contributed to an event. Find the example that best fits each potential condition; or, if there is no close parallel on the list of examples, try to find a category that is most closely related to the condition. There will be a subcategory (e.g., 1.a – goals and objectives not established) associated with the condition selected. In most cases, this will be a causal factor that contributed to the event. Apply tier diagramming and/or Five Whys or other root cause technique, to confirm the root cause and associated contributing causes. The analysis should reveal that the root cause is related to the highest level associated with the subcategory. Then construct appropriate causal statements. For example, if analysis revealed that your organization had a noncompliance because of failure to have procedures and work planning processes that implemented regulatory requirements (Subcategory 3.f), the root cause statement may be: "The root cause of the noncompliance was that the organization did not have a requirements management system that ensured work process controls (procedures and work planning) met regulatory requirements.

The overview that follows briefly describes each causal code and what it covers. The detailed listing contains the causal codes, their subcategories, and example events or conditions.

Overview of Causal Codes

1. **Planning/Organizing** (Strategy, Goals, Organization). An event or condition that exists due to the lack or inadequate analysis of process needs or roles and responsibilities and authorities; inadequate goals or objectives; design deficiencies; or insufficient development or implementation of performance strategies and prioritized actions.
2. **Directing, Leading and Decision-Making**. An event or condition that can be directly attributed to the lack or inadequacy of the managerial or supervisory approach, methods, or actions during any phase of a work activity.
3. **Work Process Controls** (Requirements Management, Procedures, Monitoring and Controlling). An event or condition that can be traced to the lack of or an inadequacy in the means used to control the work process life cycle which begins with defining applicable requirements, proceeds through work definition, planning and performance, and use of equipment and materials, and results in work product delivery.
4. **Feedback and Improvement** (Verification, Self-Assessment, Analysis, Enhancements). An event or condition caused by the lack of or inadequacy in communications, feedback, and process enhancement or continuous improvement activities.
5. **Human Factors/Competency** (Performance Variability, Resource Application, Training and Qualification). An event or condition that is due to an error, mistake, oversight, or poor judgment of those assigned to do work. An event or condition that can be traced to a lack of, inadequate, or insufficient application of resources, expertise or training that would enable a person to perform an assigned work task adequately.
6. **External Phenomenon** (Outside Forcing Functions). An event or condition caused by factors that are not controlled by the affected organizational unit.

Listing of Causal Codes and Examples

1. **Planning and Organizing**

a. Goals and Objectives Not Established

Example Events/Conditions

- Inconsistent Subordinate Objectives
- Lack of Performance Measures

b. Scope of Work and Performance Objectives Not Established

Example Events/Conditions

- Lack of Activity Focus
- Lack of Project Work Plans
- Unclear Definition of Desired Results
- Dissatisfied Customers
- Laboratory Agenda/Critical Outcomes Not Addressed

c. Design-related Deficiencies

Example Events/Conditions

- Conceptual design parameters not well defined
- Functional design requirements not adequately identified

d. Priorities Not Balanced

Example Events/Conditions

- Mission Not Translated into Work and Schedule
- No Risk Based Approach to Prioritizing Needs
- Resources Not Effectively Appropriated to Work — Insufficient Staffing Plans
- Dissatisfied Customers

e. Operational Start-up Review/Authorization Not Adequate

Example Events/Conditions

- System Failure
- Hazard Exposure

f. Inadequate Work Organization

Example Events/Conditions

- Roles and Responsibilities Not Defined or Clear
  - ❑ Duplicative Actions
  - ❑ Inadequate Accountability
  - ❑ Individual Conflicts
- Organizational Conflict

g. Methods to Reach Goals Not Determined

Example Events/Conditions

- Inconsistent Results
- Inadequate Progress
- Scope of Work Not Defined
- Milestones Not Clear

- Critical Task(s) Not Identified
- Insufficient Funding

2. **Directing, Leading, and Decision-Making**

   a. Inadequate Management Processes

   Example Events/Conditions
   - Inadequate Leadership
   - Inadequate Scheduling
   - Inadequate Work Assignment Process
   - Policy not Adequately Defined, Disseminated, or Enforced
   - Lack of Needed Resources for Approved Work

   b. Inadequate Supervision

   Example Events/Conditions
   - Poor Direction of Workers
   - Indeterminate Quality
   - Safety Exposures and Violations
   - Poor Performance
   - Poor Productivity
   - Missed Targets

   c. Inadequate Management Oversight

   Example Events/Conditions
   - Fragmented/Inefficient Operations
   - No Evidence of Management Review of Work
   - No Evidence of Management Presence at Working Level
   - Lack of Consistent Results
   - Poor Process Credibility

   d. Inadequate Subcontractor Management

   Example Events/Conditions
   - No Evidence of Management Oversight
   - Subcontractor Performance Inadequate
   - Quality Does Not Meet Contractual Obligations

3. **Work Process Controls**

   a. Scope of Work Not Defined

   Example Events/Conditions
   - No Increasing Detail of Work at Successively Lower Tiers
   - Level of Detail Is Not Commensurate with Importance, Complexity, and Potential Risks and Hazards of Work

   b. Design Implementation Process Inadequate

   Example Events/Conditions
   - Design drawings/documents inadequate
   - Design control management not adequate

- As-built conditions not documented adequately
- Design review not adequate
- Design verification inadequate

c. Hazards Not Identified/Analyzed

<u>Example Events/Conditions</u>

- Hazards Not Characterized
- Hazard Evaluation Process Not Developed or Insufficient
- Process Does Not Identify Hazards
- Hazard Analysis Not Tailored to Complexity of Work
- Subject Matter Experts (researcher, ES&H and QA), Professionals, and Workers Not Involved in Process
- Hazards Assessments Do Not Consider Accident Scenarios or Emergency Response

d. Work Performance Not Within Controls

<u>Example Events/Conditions</u>

- Hazard Controls Not Developed/Implemented
- Hazards Not Mitigated/Safety Envelopes Not in Place
- Changes in Design, Operations, or Conditions Not Properly Analyzed for Impact
- Process Not in Place to Assure Availability of Safety Systems and Equipment
- Readiness to Perform Not Confirmed
- Controls Not Tailored to Hazards Involved in Work
- Hazard Controls Not Tailored to All Stages of the Work
- Procedures Not Appropriate to Control Work and Related Hazards
- Work Activities Not Properly Authorized
- Operational Start-up Review Not Adequate
- Change Control Process Not In Place
- Safety Requirements Not Integrated into Work Performance
- Hazard Exposure
- Injuries
- Failure of Experiment(s)

e. Equipment or Materials Issues

<u>Example Events/Conditions</u>

- Wrong Equipment or Material Specified or Used
- Inappropriate Application of Equipment or Materials
- Materials Processed Incorrectly
- Equipment or Material Failure
- Insufficient Maintenance
- Design Life Exceeded

f. Poor Identification of Safety Standards and Requirements — Inadequate Requirements Management System

<u>Example Events/Conditions</u>

- Requirements Not Identified or Known
- Requirements Do Not Flow Down from Institutional to Work Activity Level
- Requirements Not Effectively Translated Into Policies and Procedures

- Processes Do Not Address Implementing New Requirements
- Requirements Not Tailored to Hazards or Work Activity
- Procedures Do Not Reflect Requirements
- Noncompliance
- Regulatory Findings
- Enforcement Actions

g. Procedures Not Used or Followed Correctly

Example Events/Conditions

- Unexpected Results
- Noncompliant Conditions
- Inconsistent Results
- Compliance Issues
- Regulatory Scrutiny
- Enforcement Actions

4. **Feedback and Improvement**

a. Self-Assessment and Performance Measurement Not Adequate

Example Events/Conditions

- Insufficient Methods and Processes for Collecting Information on Performance
- Lack of Performance Measures
- Process Does Not Address Both Compliance and Performance
- Causal Factor Analysis is Inadequate (Does Not Identify Causes)
- There are No Formalized Feedback Mechanisms to Obtain Input from Workers, Supervisors, and Line Management
- Results of Assessments are Not Communicated to Management
- Subcontractor Performance Is Not Monitored
- Process Does Not Measure Performance Against Objectives
- Process Does Not Identify Opportunities for Improvement

b. Lack of Follow-up and Corrective Actions

Example Events/Conditions

- There Is No Formalized Process to Track and Trend Deficiencies and Associated Corrective Actions
- There Is No Process for Assigning Responsibility or Milestones for Corrective Actions
- There Is No Risk-Based Prioritization for Corrective Actions

c. Improvements Not Implemented

Example Events/Conditions

- Inadequate Management Support
- Closure of Corrective Actions Not Based on Objective, Verified Evidence
- No Budget/Resource Allocation Available

5. **Human Factors/Competency**

a. Human-Machine Interface Problem

Example Events/Conditions

- Unanticipated Results
- Disrupted Work
- Invalid Results
- Hazard Exposure
- Injuries

b. Working Environment Issue

<u>Example Events/Conditions</u>

- Health Problems
- Manager/Worker Conflict
- Ergonomics
- Worker/Worker Conflict
- Inefficient Work

c. Staff Member Not Qualified To Do Assigned Work

<u>Example Events/Conditions</u>

- Deficient Items/Services
- Inefficient Operations
- Exposure To Hazards
- Dissatisfied Customer

d. Complex System Operational Interface

<u>Example Events/Conditions</u>

- Performance Errors
- Inconsistencies
- Worker Stress

e. Single-failure Modes in System

<u>Example Events/Conditions</u>

- No Room for Error
- Unrecoverable Situation
- Increased Risk of Hazard Exposure

f. Poor Judgment

g. Fitness for Duty—Physically and/or Mentally Impaired

h. Verbal or Written Communication Problem

i. Inattention to Detail

j. Noncompliance with Procedure/Requirement

k. Unfamiliar Application

l. Staffing and Qualifications

<u>Example Events/Conditions</u>

- Critical Skills Not Identified
- Technical Expertise Not Appropriate for Work Performed
- Qualifications Not Current
- No Process to Ensure Adequate Levels of Management and Staff Resources and Technical Expertise
- Critical Skills Not Linked to Qualifications for Job

m. Competence Not Commensurate with Responsibilities

Example Events/Conditions

- Technical Competence for Job Not Appropriate
- Appropriate Qualified and Competent Personnel Not Assigned to Work
- Staffing and Equipment Malfunction/Failure
- Invalid Work Results
- Responsibilities Not Understood
  - ❑ Hazard Exposure
  - ❑ Duplications/Omissions
  - ❑ Invalid Work Results
- Knowledge Not Adequately Applied
  - ❑ Inadequate Understanding of Cause and Effect
  - ❑ Exposure to Hazard
  - ❑ Incident/Accident/Noncompliance

- Lack of Hands-on Experience/Insufficient Practice
  - ❑ Exposure to Hazard
  - ❑ Incident/Accident/Noncompliance
  - ❑ Inadequate Evaluation of Training to Improve Delivery

n. Training Deficiency

Example Events/Conditions

- No Training Provided
- Training Does Not Assure Effective Measures that Improve Performance
- Inadequate Training Content/Materials
- Inadequate Presentation of Training
- Inadequate Validation That Training Meets Objectives
- Inadequate Trainers and Instructors
- Inadequate Program Documentation To Verify Qualifications Current
- Inadequate Work Process Knowledge
- Inadequate Understanding of Technical and Regulatory Requirements

o. Communication Error

Example Events/Conditions

- Poor Understanding of the English language
- Lack of Process Understanding
- Poor Understanding of Responsibilities
- Inadequate Understanding of Cause and Effect

6. **External Phenomenon**

a. Inclement Weather Conditions

Example Events/Conditions

- Flood
- Tornado
- Hurricane
- Fire
- Hail

- Earthquake
- Extreme Hot
- Extreme Cold
- Snow

b. Power Failure/Transients

c. External Fire or Explosion

d. Biological or Toxic Agent Exposure

e. Theft, Sabotage, Bomb Threat, Intrusion or Vandalism

f. Air, Rail, Ship, or Highway Accident

APPENDIX C

COMPARISON BETWEEN

BATTELLE AND ORPS

CAUSAL CODES

ORPS Codes	Battelle Codes
1 - Equipment/Material Problem. An event or condition resulting from the failure, malfunction, or deterioration of equipment or parts, including instruments or material.	
1A - Defective or Failed Part. A part/instrument that lacks something essential to perform its intended function.	3. Work Process Controls e. Equipment or Materials Issues
1B - Defective or Failed Material. A material defect or failure.	
1C - Defective Weld, Braze, or Soldered Joint. A specific weld/joint defect or failure.	
1D - Error by Manufacturer in Shipping or Marking. An error by the manufacturer or supplier in the shipping or marking of equipment.	2. Directing, Leading, and Decision-Making d. Inadequate Subcontractor Management
1E - Electrical or Instrument Noise. An unwanted signal or disturbance that interferes with the operation of equipment.	
1F - Contaminant. Failure or degradation due to radiation damage or foreign material such as dirt, crud, or impurities.	
1G - End of Life Failure. A failure where the equipment or material is run to failure and has reached its end of design life.	3. Work Process Controls e. Equipment or Materials Issues
2 - Procedure Problem. An event or condition that can be traced to the lack of a procedure, an error in a procedure, or a procedural deficiency or inadequacy.	
2A - Defective or Inadequate Procedure. A procedure that either contains an error or lacks something essential to the successful performance of the activity.	3. Work Process Controls f. Poor Identification of Safety Standards and Requirements — Inadequate Requirements Management System
2B - Lack of Procedure. No written procedure was in place to perform the activity.	1. Planning and Organizing b. Scope of Work and Performance Objectives Not Established

ORPS Codes	Battelle Codes
3 - Personnel Error. An event or condition due to an error, mistake, or oversight.	
3A - Inattention to Detail. Inadequate attention to the specific details of the task.	5. Human Factors/Competency i. Inattention to Detail
3B - Procedure Not Used or Used Incorrectly. The failure to use or the inappropriate use of written instructions, procedures, or other documentation.	3. Work Process Controls d. Work Performance Not Within Controls
3C - Communication Problem. Inadequate presentation or exchange of information.	5. Human Factors/Competency o. Communication Error
3D - Other Human Error. Human error other than those described above.	5. Human Factors/Competency
4 - Design Problem. An event or condition that can be traced to a defect in design or other factors related to configuration, engineering, layout, tolerances, calculations, etc.	
4A - Inadequate Work Environment. Inadequate design of equipment used to communicate information from the facility to a person (e.g., displays, labels, etc.) as well as inadequate work environment, such as inadequate lighting, working space, or other human factor considerations.	5. Human Factors/Competency b. Working Environment Issue
4B - Inadequate or Defective Design. A design in which something essential was lacking (defective) or when a detail was included but was not adequate for the requirement (inadequate).	3. Work Process Controls b. Design Implementation Process Inadequate
4C - Error in Equipment or Material Selection. A mistake in the equipment or material selection only, not to include a procurement error (see Personnel Error - (e) Other Human Error) or a specification error (see Design Problem - (d) Drawing, Specification, or Data Errors).	3. Work Process Controls e. Equipment or Materials Issues
4D – Drawing, Specification, or Data Errors. An error in the calculation, information, or specification of a design.	b. Work Process Controls b. Design Implementation Process Inadequate

ORPS Codes	Battelle Codes
5 – Training Deficiency. An event or condition that can be traced to a lack of training or insufficient training to enable a person to perform a desired task adequately.	b. Human Factors/Competency n. Training Deficiency
5A – No Training Provided. A lack of appropriate training.	
5B – Insufficient Practice or Hands-On Experience. An inadequate amount of preparation before performing the activity.	
5C – Inadequate Content. The knowledge and skills required to perform the task or job were not identified.	
5D – Insufficient Refresher Training. The frequency of refresher training was not sufficient to maintain the required knowledge and skills.	
5E – Inadequate Presentation or Materials. The training presentation or materials were insufficient to provide adequate instruction.	
6 – Management Problem. An event or condition that can be directly traced to managerial actions or methods.	
6A – Inadequate Administrative Control. A deficiency in the controls in place to administer and direct activities.	b. Directing, Leading, and Decision-Making a. Inadequate Management Processes
6B – Work Organization/Planning Deficiency. A deficiency in the planning, scoping, assignment, or scheduling of work.	b. Planning and Organizing
6C – Inadequate Supervision. Inadequate techniques used to direct workers in the accomplishment of tasks.	b. Directing, Leading, and Decision-Making b. Inadequate Supervision
6D - Improper Resource Allocation. Improper personnel or material allocation resulting in the inability to successfully perform assigned tasks.	2. Directing, Leading, and Decision-Making a. Inadequate Management Processes
6E - Policy Not Adequately Defined, Disseminated, or Enforced. Inadequate description, distribution, or enforcement of policies and expectations.	3. Work Process Controls a. Scope of Work Not Defined
6F - Other Management Problem. A management problem other than those defined above.	2. Directing, Leading, and Decision-Making 3. Work Process Controls

ORPS Codes	Battelle Codes
7 - External Phenomena. An event or condition caused by factors that are not under the control of the reporting organization or the suppliers of the failed equipment or service.	6. External Phenomenon
7A - Weather or Ambient Condition. Unusual weather or ambient conditions, including hurricanes, tornadoes, flooding, earthquake, and lightning.	6. External Phenomenon a. Inclement Weather Conditions
7B - Power Failure or Transient. Special cases of power loss that are attributable to outside supplied power.	6. External Phenomenon b. Power Failure/Transients
7C - External Fire or Explosion. An external fire, explosion, or implosion.	6. External Phenomenon c. External Fire or Explosion
7D - Theft, Tampering, Sabotage, or Vandalism. Theft, tampering, sabotage, or vandalism that could not have been prevented by the reporting organization.	6. External Phenomenon d. Theft, Sabotage, Bomb Threat, Intrusion or Vandalism
8 - Radiological/Hazardous Material Problem. An event related to radiological or hazardous material contamination that cannot be attributed to any of the other causes.	
8A - Legacy Contamination. Radiological or hazardous material contamination attributed to past practices.	
8B - Source Unknown. Radiological or hazardous material contamination where the source cannot be reasonably determined.	

APPENDIX D

THE SEVEN DEADLY SINS OF QUALITY MANAGEMENT

BY JOHN DEW

The Seven Deadly Sins of Quality Management

by John Dew

In 50 Words Or Less
- Root cause analysis must dig deep to the values and beliefs of an organization.
- Any one of seven belief systems can create management disfunctionality.
- A new taxonomy will help organizations unearth the truly fundamental problems with management systems.

Root cause analysis is a somewhat arcane specialization within the quality body of knowledge. Some quality professionals are understandably wary of the methodology since it can be used in ways that lack rigor.

Background

As a discipline, root cause analysis has its origins in the nuclear branch of the U.S. Navy, when Admiral Hyman Rickover set a high standard of performance for operational systems and personnel. Most of the early root cause analysis methods were developed through collaboration between nuclear Navy personnel and staff at the Atomic Energy Commission (AEC, today called the Nuclear Regulatory Commission or NRC), who were concerned with the design, operation, maintenance and fueling of naval nuclear reactors.

As a result of the Three Mile Island nuclear reactor meltdown incident in 1979 and the review of research reactor operations at the national laboratories, root cause analysis methods became more widespread within the nuclear industry and at government nuclear weapons and research facilities.[1]

Most current publications and training materials in the field of root cause analysis were written by former nuclear quality assurance personnel, such as Dean Gano,[2] Max Ammerman[3] and Mark Paradies.[4]
Safety professionals in the field of accident investigation quickly found the root cause analysis methods developed by the Navy and AEC were very effective in analyzing specific accidents. Root cause analysis began to creep beyond the field of nuclear operations into the general body of knowledge used by health and safety professionals.

As ASQ members in the Energy and Environmental Division began examining opportunities for integrating quality, environmental, health and safety practices, root cause analysis soon emerged as one of the common methods that can benefit all of these professions.

More recently, the Joint Commission for Accreditation of Healthcare Organizations has recommended the use of root cause analysis methods for the analysis of significant quality failures (called sentinel events) in hospitals and other healthcare settings.

What Is Root Cause Analysis?

Root cause analysis is a structured questioning process that enables people to recognize and discuss the underlying beliefs and practices that result in poor quality *(safety)* in an organization.

A root cause is a basic causal factor, which if corrected or removed will prevent recurrence of a situation. There is honest disagreement as to whether an error can be attributed to a single root cause (something that has the absolute effect of a light switch) or whether there will be a cluster of root causes. This may depend on the taxonomy of root cause definitions adopted by an organization.

The methods of inquiry that constitute root cause analysis are useful for both the diagnosis and prevention of quality, environmental, health and safety problems. What some practitioners are reluctant to admit is that root causes reside in the values and beliefs of an organization. Until the analysis moves to this level, an organization has not begun to grapple with root causes.
An appropriate rule of thumb for knowing how deep to dig in conducting a root cause analysis is to dig until you reach the point of admitting something really embarrassing about the organization, but don't go so far that you are in the field of theology. In other words, we should focus on studying the systems we use to manage an organization and the beliefs and behaviors that shape these management systems, but we should not drift into attempts to answer questions about humanity's place in the universe.

Taxonomies of Root Cause
Effective root cause analysis requires both the use of a variety of methodologies and the adoption of a taxonomy of root causes that digs deep enough to foster discussion about the real root causes of problems.

A taxonomy is a method for organizing and classifying information. Biology students are accustomed to learning taxonomies of organisms. A body of knowledge, such as quality, is often organized by a taxonomy that seeks to identify major categories.

The immediate benefit of having a taxonomy of root causes is that it helps identify the end point in the questioning process and allows organizations to tally the number of times problems occur in a specific root cause area.

If the taxonomy of root causes is organized around observations that are not truly root causes, then the questioning process may be prematurely ended and the organization may continue to suffer from the unnamed root cause.

Many organizations currently employ taxonomies that describe root cause categories in terms of inadequate control of management systems, inadequate training, inadequate use of procedures, inadequate communications and other classifications. None of these are actual root cause categories. Conducting a root cause analysis process that ends the inquiry at these levels is misleading and poorly serves organizations that are in need of critical feedback to survive.

I worked in one organization that religiously conducted root cause analysis of all major and minor reportable occurrences in preparation for regulation by the NRC. A team was charged with conducting root cause analysis and tracking and trending the categories of root causes of the facility's events.

After more than a year of analysis, the team found the majority of events were in the category of inadequate management oversight. **At no time did the process lead to a meaningful discussion of the root causes--the values and beliefs embedded in the organization that justified and reinforced the behavior of management.** Thousands of hours of analysis revealed what every quality professional already knew, based on W. Edwards Deming's observation that most problems are management controllable--embedded in the manner in which management decides to operate the organization.[5]

If management's operational decisions are based on a set of prevalent beliefs within an organization, what does this understanding lead us to do next? To enable organizations to dig more deeply and to dig more bravely, a new taxonomy of root causes would be useful. This new taxonomy should focus on the management issues people will discuss until a postmortem of an organization is being conducted.

A New Taxonomy of Root Causes
I tested a new taxonomy of root causes with quality professionals at ASQ's 2002 ISO 9000/14000 Conference and 2002 Annual Quality Congress.[6] As a result of encouraging responses from peers at those events, it is now possible to advance it for wider critique among more quality professionals.

The purpose of this taxonomy is to drive the process of critical thinking to deeper levels within organizations that purport to practice root cause analytical thinking. This taxonomy seeks to un-earth the truly fundamental problems with management systems in any organizational setting.

This new taxonomy categorizes root causes into seven belief systems, any one of which can create extreme dysfunctionality in a management system.

Until management recognizes its belief system, understands how these beliefs create dysfunctional behaviors and then embarks on a journey to develop new beliefs and behaviors based on the quality body of knowledge, it cannot extract itself from its quandary.

The new taxonomy includes:
1. Placing budgetary considerations ahead of quality *(safety)*.
2. Placing schedule considerations ahead of quality *(safety)*.
3. Placing political considerations ahead of quality *(safety)*.
4. Being arrogant.
5. Lacking fundamental knowledge, research or education.
6. Pervasively believing in entitlement.
7. Practicing autocratic behaviors, resulting in "endullment."

1. Placing budgetary considerations ahead of quality. In this root cause category, management does not understand the fundamental concept of the cost of quality, as defined by Philip Crosby[7] and Frank Gryna.[8] Obtaining quality in performance and service is still viewed as an expense, rather than an indispensable element for profitability. Key decisions are made based on accounting principles that do not recognize the concept of the cost of (poor) quality.

Many in the quality profession have been highly successful in implementing methods, such as statistical tools and project teams, only to witness overall failure of the management system due to a lack of understanding of the economics of quality among senior management. **This leads to a wide variety of dysfunctional behaviors that undermine quality, environmental, health and safety performance.**

2. Placing schedule considerations ahead of quality. When quality processes are in place, schedules will be met. But many organizations do not believe they can take the time to do things right the first time, although they spend a great deal of time on rework and response to customer complaints**.** Many organizations succumb to meeting deadlines, even when they know they are not providing a quality product or service.

Being schedule driven causes quality problems to be ignored, inevitably leading to an inability to meet schedules. This, in turn, ultimately drives up the cost of products and services since there will be penalties, lost sales and rework caused by missing schedules.

Unfortunately, this root cause has been encouraged by national consultants who have advised organizations to move hastily and not to take the time for adequate planning and assurance of quality.

"Ready, fire, aim" has been the practice of troubled organizations, along with the equally inane slogan of "faster, better, cheaper."

3. Placing political considerations ahead of quality. In some organizations it is not possible to discuss problems that may exist. In fact, mentioning a problem can be a career limiting move. Sometimes this is because acknowledging the problem will reveal past efforts to fix it have been unsuccessful.

In some cases, an important person will be offended if the problem is discussed, so it is ignored. In other cases, a problem is well recognized within an organization, but is kept hidden so clients, customers or the public will not learn about it and possibly develop a bad impression of the organization.

All this flies in the face of Deming's admonition to drive fear out of the organization.[9] Placing political considerations ahead of quality is the antithesis of good internal auditing. However, people who have the courage to talk about problems are then labeled as whistle-blowers and are often punished in both overt and subtle ways.

When political considerations rule, problems fester and grow. Loyal employees can become disillusioned and leave.

4. Being arrogant. Our organization is made up of the best minds in our field. We've graduated from the top universities. We are surgeons. **We are physicists**. We are the largest company in this field. We've been in this business for over 100 years. We have top level security clearances. We invented this technology. We hold more patents than any other company. We have the top scholars in the field. We ride in private jets. We have private boxes at big sporting events.

Once organizations begin to use these types of rationalizations to justify their actions, they are composting a soil of arrogance that will ultimately sprout significant quality, environmental, health and safety problems.

Some of our nation's biggest quality failures have been due to a climate of arrogance in important organizations. Arrogance has been shown to be a root cause in medical mistakes, the crash of airplanes and in major man-made environmental disasters.

Any organizational culture that creates an environment in which the captain, chief surgeon, scientist, pilot or president cannot be viewed as capable of making a mistake and cannot be questioned has embraced an arrogance that will ultimately lead to disasters. The ancients called this excessive pride or self-confidence "hubris."

5. Lacking fundamental knowledge, research or education. There is great truth in the old saying, "You don't know what you don't know." In some cases, people embark on new projects without fully understanding what the outcomes will be, which is fine if the lack of understanding is taken into account.

When we sail into new territories and have made contingency plans for things that might go wrong, we are doing pioneering work. When we rashly embark on a journey with no consideration of the adverse consequences, we are taking unnecessary risks that can lead to significant failure.

Nowhere can this be more clearly seen than with reactor operators conducting unauthorized experiments at the nuclear power reactor in Chernobyl in the former Soviet Union.[10]

Groundwater contamination incidents, newly designed equipment that does not work and new oil rigs that sink are other results of organizational cultures that do not value knowledge and research before taking action.

The principles of quality assurance--such as independent verification, testing, auditing and calibration control--are denigrated as being unnecessary, burdensome and anal retentive.

6. Pervasively believing in entitlement. In some cases, management adopts a laissez-faire attitude, permitting the employees to believe they actually run the organization.

Employee participation is a positive attribute, and in a few cases, employees really do own the company. This is a corporate model that works very well in a variety of settings and does not generally lead to a belief in entitlement.

The entitlement belief system is one in which employees believe they are entitled to their jobs and their benefits due to years of service, past sacrifices and past performance. They believe they should be immune to the vagaries of market forces, impact of new technologies and changes in customer requirements.

When the belief in entitlement is pervasive, employees believe no one else would want to have their job and put up with all they have to put up with. They expect raises every year, regardless of the organization's performance.

The entitlement mentality is sometimes associated with a union. But unions do not necessarily foster a sense of entitlement, and a sense of entitlement can be prevalent in nonunion organizations.

Entitlement is created by management's failure to continually share business and performance information with the workforce--with or without a union.

7. Practicing autocratic behaviors, resulting in "endullment." Endullment is the condition identified by Ira Shor as the opposite of empowerment.[11] Shor says when high school students have no sense of control over or involvement in what they are forced to study, they turn off, passively resist, become apathetic, fail to complete assignments and fail to attend classes.

The same phenomena occur when management adopts an autocratic approach to decision making and does not share information with the workforce, does not provide a balanced scorecard or performance indicators and does not engage the members of the workforce in a collaborative effort to continuously improve their performance to secure their mutual economic well-being.

In the endullment setting, employees talk about being mushrooms--kept in the dark by management and fed manure. Many of the early efforts to develop team based organizations ran smack into the issues of autocratic leadership and the resulting sense of endullment, and stopped right there.
Likewise, many attempts by quality professionals to engage the workforce in collaborative continuous improvement are fruitless until the anger and resentment regarding autocratic leadership are resolved.

Self-perpetuation
Leaders who succumb to any of these seven fundamental root causes will not want to acknowledge their problem. Organizations struggling with one or more of these issues are similar to the family of an alcoholic who is in denial. Everyone tiptoes around the problem and will not name it. It is like having an elephant sitting in the living room that no one is willing to acknowledge.

This is why quality *(safety)* has been viewed as a fad in many organizations. People hear the quality message, and leaders embrace the quality lingo, but when quality principles and methods run into the deeply entrenched dysfunctional belief system in an organization, quality is tossed out and condemned. Managers denigrate quality concepts as a fad and turn back to their focus on costs, schedule, political manipulation, arrogance, ignorance, entitlement or endullment.

The problem is not that quality professionals do not speak the language of senior management, but that in some organizations, senior management does not know the fundamental lessons of quality and is not interested in learning.

The culture in any organization tends to be self-perpetuating in that managers will select people for promotion whose espoused values and visible behaviors reflect the sentiments of the managers in charge. If few quality managers make it into senior management positions, it may be because, in some organizations, senior management does not really believe in the quality concepts.

Root cause analysis is an essential process for any organization that wants to continue to improve and is willing to engage in serious introspection and analysis. However, we must be willing to dig deep enough to uncover and consider the beliefs and behaviors that shape an organization's management system.

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